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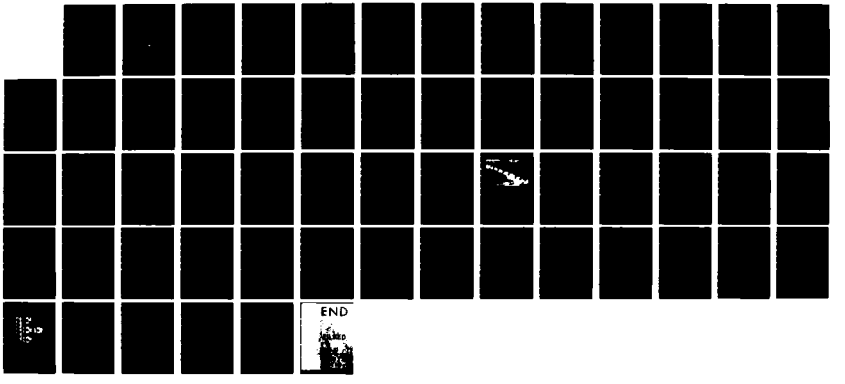

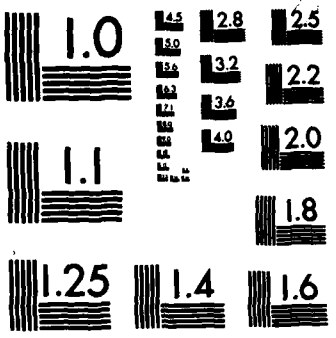

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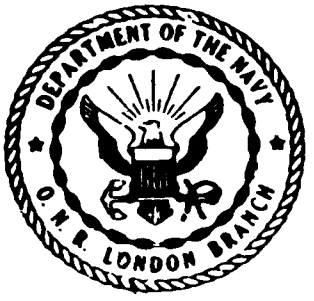

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European Scientific Notes (ESN) is a monthly publication with brief articles on recent developments in European Scientific research. The publication is not intended to be part of the scientific literature. The value of ESN articles to Americans is to call attention to current developments in European science and technology and to the institutions and people responsible for these efforts. ESN authors are primarily ONRL staff members. Occasionally articles are prepared by or in cooperation with staff members of the

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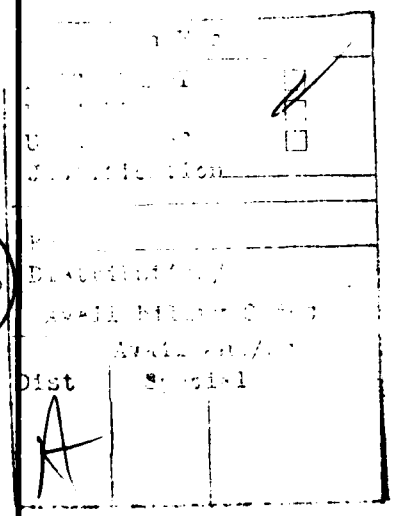

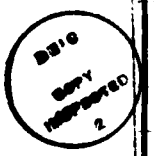

EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Edited by Vivian T. Stannett
Larry E. Shaffer

Vol 37, No. 1 31 January 1983

BEHAVIORAL SCIENCES

Europe's most advanced ship simulator will be used in many training and research programs.

CHEMISTRY

High polymers were a major focus of the meeting. The article concentrates on radiation processing concerned with polymers and on crosslinking.

The technical program included sessions on topics such as the dynamics of reactions, biomolecular reactions, and laser-induced and complex processes.

COMPUTER SCIENCES

Expert systems are computer-based systems in which collected information--including rules, procedures, methods, and data on some particular professional or technical activity--are provided in usable form to someone who may not be a specialist in that activity. This article describes the subject in general and its application to the field of corrosion metallurgy.

The research in robotics at Institut de Recherche en Informatique et Systems Aleatoires (IRISA), Rennes, France, is reviewed. The two principal areas are in sensing of the environment and in controlling the robot.

The work in robotics research at Laboratoire d'Automatique et d'Analyse des Systems, Toulouse, is reviewed. The three principal projects are experimentation with an autonomous mobile robot, identification and localization of partially observed parts, and control of robots for assembly.

ELECTRONICS

MATERIAL SCIENCES

OCEAN SCIENCES

OPERATIONS RESEARCH

PHYSICS

PSYCHOLOGY

SPACE SCIENCE

TECHNOLOGY

NEWS & NOTES

ESN 37-1 (1983)

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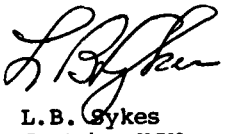
F.A. Richards
Chief Scientist



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BEHAVIORAL SCIENCES

THE CARDIFF SHIP SIMULATOR

The main advantages of a ship simulator are obvious: crews can practice conveniently on dry land, dangerous or unusual operating conditions can be experienced without real risk, task and equipment configurations can be evaluated, procedures can be modified, readiness and certification testing of whole crews can be done.

The art of interpreting navigational aids may be taught better in a simulator than anywhere else. Therefore, every Naval or maritime institute has simulator facilities, and there are at least eight ship simulators in Europe that produce some kind of bridge scenery and control facilities. The installations vary widely in their realism, with some producing dynamic color pictures and others showing a rather bare "bridge pattern" of a few projected lights.

Some uses for ship simulators are less obvious. Recently, a simulator "playback" or walkthrough of the events preceding a famous ship collision off the British coast was admitted as evidence in the legal hearings on the incident. Another use, which will be important as shipping becomes more specialized, is the capability of simulators to evaluate ship operations in new ports and loading facilities. Here the term "new" can refer to ports that are still in the design stage, or it can mean ports, say those of a potential military enemy, that are unavailable for maritime exercises. Simulators can also help planners make as effective as possible the layout of approach channels, the alignment of jetties, and the establishment of dredging schedules, for example.

The expense of actual port redesign or modification is so high that a simulator used for design can pay for itself rather quickly. A good current illustration comes from the Arctic liquefied natural gas (LNG) carriers, which will soon come into service; the delays in full-ahead-to-full-astern in such ships must be only a fraction (about 20%) of those in similarly sized ships now operating. Since achieving such short control lags will be critical in the successful use of the Arctic LNG carrier, thorough evaluations with simulators are being done before Arctic operations are attempted.

The CASSIM Project

The most advanced ship simulator in Europe is now operating in Cardiff, Wales, at the Univ. of Wales Institute of Science and Technology (UWIST). As in most such installations, several government and industrial agencies were involved in the Cardiff ship simulator (CASSIM) project. Marconi UK was the principal contractor for the displays and the electronics. The design philosophy of CASSIM reflected the technical requirements of the 1980s and beyond, and exploited the most recent advances in computer and display technologies. The key concept was diversity: there would be a need to reproduce the essentials of many ship and engine types, locations, and procedural options. Diversity has been achieved by general display devices and picture generators, which operate on the output from a computer configuration (Figure 1). Any scene or ship configuration or instantaneous sea-state condition can be computed from a special data base coded in digital form. Simply change the data base, and a whole "new world" of ships, ocean, and port facilities appears. Such an approach to diversity is qualitatively different from the older analog models, in which a physical model of a port area was built, and a TV camera "flew" over the model.

Computer-generated imagery (CGI) models of dynamic ship behavior require hydrodynamic models that include, in addition to the usual ship forces in the water, some terms for complexities such as wind, bank, stream and tidal currents, and waves. The idea is to get an acceptable simulation that can be computed practically in nearly real time. Big simulators like CASSIM have large support staffs, who develop their own arts of managing the tradeoffs between the variables of accuracy, practicality, realism, and expense. Because the CASSIM simulator must "earn

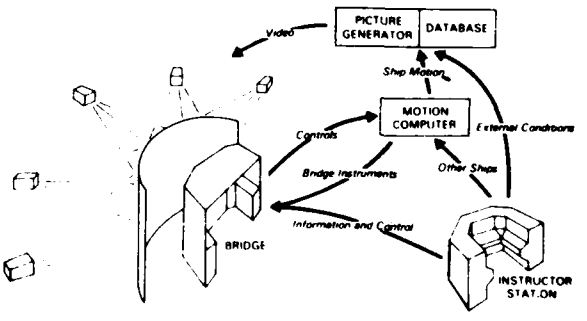

Figure 1. CASSIM layout.

its keep" and must serve many customers, it is extraordinarily flexible, and apparently it can accept nearly any geographic, hydrodynamic, or engine-room data base.

The Bridge

The visitor who walks intcc the CASSIM bridge when it is operating like an ordinary tanker would quickly notice that the bridge "feels" like a ship; this is due to the lighting and to fairly realistic vibrations in the floor, which are correlated with engine speed. Perhaps the next thing to be seen is an image of the front part of own ship, looking toward the bow; the image is stationary and extremely realistic, as it is projected by a slide projector onto a nearly transparent screen. A few feet behind the image screen there is a larger curved screen, which nearly wraps around the bridge and which can show the ocean, other ships, airplanes, helicopters, navigational markers, and ground detail. All the surfaces and objects shown on the screen are computer-generated, and while they may look distinctly "geometrical" and artificial, they are easily recognized.

A lighthouse, for example, may be shown as an elongated white trapezoid; but such a white trapezoid standing on a flat piece of brown rectangular "land" does indeed look enough like a lighthouse to be identified instantly as the lighthouse on the chart. Also, the lighthouse "grows" in true perspective as you approach or turn away from it; so do all the other computer-generated objects, such as ships, quays, and piers. And the closer you get, the more detail you see; a window may appear in the lighthouse, for example, at 500 yd, but not at 1,000 yd. It is hard to say exactly how many buildings, other ships, and ground features can be programmed to appear, because much will depend on the degree of detail required. But it is clear that CASSIM has the computing and storage capabilities for producing very complex configurations. For demonstration runs, the Milford Haven port area of Britain is now accessible in a detailed data base. Visitors can have the experience of guiding a standard tanker into port.

Reportedly, much of the dynamic graphics is produced by means of triangles: a simple lighthouse is made of two triangles, a ship may be constructed out of eight or a dozen triangles, a line of beach or cliff land takes anywhere from two to six triangles, and so forth. The data base triangle edges are "clipped" to reflect the facts about "obscured" parts, and are then operated upon by the perspective geometry equations, which in turn are driven by the ship movement equations and the instantaneous ship parameters at any given moment.

Many display compromises and tradeoffs are evident to the observer. For instance, the "helicopter" which "takes off" from a carrier in Milford Haven harbor appears to be about half as big as the carrier itself. But it is obviously a helicopter even though the scale is not accurate. There must be some subtle psychophysics in all this moving information that the human operators see from the bridge. And though CASSIM apparently furnishes no moving texture distributions on the ground features, the overall appearance of depth of a typical harbor scene is quite striking. The wave simulation, which is superimposed on the water, might be considered a pseudo-textural effect, as the nearby waves are larger and the the ripples always move in the direction of apparent water flow.

Many manual modifications can be made as the system runs. The controller can insert fog or other weather changes, engine, control, or communications failures into the system. Such conditions are generally recorded automatically, thus furnishing management a good gauge of the trainee's ability to handle the incidents.

Data-base preparation is still something of an art because many little decisions and compromises have to be made regarding degree of detail and selection of pictorial features to be represented. The CASSIM management believes that it would now take several man-months to code up a typical port area, but the time may be reduced as experience is gained. At one briefing it was stated that gross data base information was available on nearly all the significant port and coastal areas of the world, and that much of this information can be updated readily from satellite and other sources. There have been proposals for systematizing the data-base preparation, and perhaps aiding it by computer-driven compilation routines. Perhaps more than 90% of the port information is conservative and does not change quickly. CASSIM researchers believe that some of the basic mathematical research on edge detection and shape definition will eventually be applied in data bases for big simulators.

Other Research

Projects like CASSIM always spawn many specialized research efforts. A track-keeper study, now being done by

applied mathematicians at UWIST, is defining an optimal navigational policy for a restricted waterway. Among the important issues being investigated are: (1) equations that are good enough for simulation purposes and that can still be computed on-line, and (2) the statistical robustness of a track-keeper model against Gaussian wind, current, and navigational fix errors. Some tracks for the Milford Haven harbor entry have been obtained under different controller models. The work is continuing, but it is already clear that extremely accurate tracks can be obtained with the models--at the cost of computer time and many small rudder and propeller adjustments.

Realistic tidal current variables have been played into some of the simulator runs, with overall satisfactory track-keeping performance. A replay of many simulated harbor entries has already furnished port management with an idea of what can be expected from near-optimal controllers operating in real harbor areas such as Milford Haven. When several dozen runs in that harbor were overlaid, it was obvious that one sharp turn in the harbor produced most of the variance.

Engine-Room Simulators

Engine-room simulators are not as dramatic as bridge simulators, and often have been built to mimic one particular engine installation. But the field is gradually responding to present computer capabilities. Project HAMSES (Haven Automation Marine Machinery Simulation Equipment), for instance, provides the customer several engine options. Many people, including the CASSIM staff, are working on or monitoring the HAMSES simulator; mathematical modeling studies are under way at the Royal Naval College, Greenwich (UK), and the Sulzer diesel engine firm in Winterthur, Switzerland, has provided engine operating parameters.

CASSIM analysts classify engine system models as either steady state or dynamic. In the steady-state models, operating system curves are derived from manufacturers' specifications, and the system is "jumped" from one curve to another to simulate transient performance. Steady state analysis is often unsuitable for failure simulations, however, because the operating curves under failure usually do not exist, and the manufacturer would not test his equipment under failed conditions anyway. A "dynamic" approach models the system in a series of equations which can be chosen so that they remain valid under failure conditions. One can model a fault and watch the behavior develop throughout the system. There is still much art in expressing such equations and in setting parameters for them. At the Royal Naval College, for instance, analysts may essentially do some trial settings of physical potentiometers in order to tune the equations for the best fit.

Validity

Psychologists who have been close to aircraft simulator projects will be curious about the validity of CASSIM, and will want to know whether it produces economical transfer of training. The system certainly seems to be valid, and the smooth dynamics, realism, and color are attractive to nearly all observers; even though there are "joints" and edges in the projection screen, objects move across the edges quite realistically. But the CASSIM people know that attractiveness is not effectiveness. One experimental trial, nearing completion now, involved a small sample of Royal Navy operators who spent 2½ intensive days in CASSIM working on ship-handling problems of gradually increasing difficulty. The group will be compared with a sample of operators who had actual sea runs near Cardiff.

A 6-month follow-up is planned; from other studies of long-term transfer, one might predict rather slight positive transfer. But many variables influence transfer, and sometimes the most important ones are outside simulator control. CASSIM should be an excellent test bed for evaluating transfer schemes and training plans; the system can be easily reset and graded for the difficulty of a lesson. For "overlearning" of ship control in ports, perhaps no other simulator is so well suited for intensive practice.

From all indications, CASSIM will be the most general ship simulator in Europe for some time. Can characteristics of the next generation of simulators be forecast now? With a probable improvement of several orders of magnitude in computing power and more experience in building gigantic but flexible data bases, a decade or so from now we can expect prettier and more detailed pictures and more of the ship's environment to be presented. But can we expect more adequate theories of transfer and human learning as a result of using these marvelous big simulators?

A. Bond, Jr.

CHEMISTRY

FOURTH INTERNATIONAL MEETING ON RADIATION PROCESSING

The Fourth International Meeting on Radiation Processing was held in Dubrovnik, Yugoslavia, from 4 through 8 October 1982; 268 delegates from 34 countries participated, including 44 from the US. Nearly one third of the 130 papers and posters presented were concerned with high polymers, which this article discusses.

Many presentations were concerned with other aspects of radiation processing: for example, radiation sterilization, food irradiation, environmental applications, and radiation chemistry applied to nuclear technology. Engineering and economic aspects discussed included electron beam and isotope source technology, dosimetry, and quality control. Three special panel sessions were held on "Material Problems in Radiation Sterilization," "Absorbed Dose Specifications in Sterilization," and "Technology Transfer in Radiation Processing."

The keynote address was by C.E. Snyder, Goodyear Tire and Rubber Co., one of the world's largest users of high energy radiation for industrial processing. The development of industrial applications and prospects for high energy radiation were reviewed. In spite of a number of disappointments and false starts, a growth rate of 15 to 25% worldwide has been steadily maintained; now more than $2 billion worth of products are being irradiated each year. It was pointed out that radiation has been most successful in spawning new industries. However, well-established industries are in desperate need of process cost savings, which radiation often can provide. Areas presently showing considerable research activity and large scale industrial potential were then discussed.

Progress in such areas and well-established applications were then reviewed in invited lectures, contributed papers, posters, panels, and discussions.

Radiation Processing Concerned With Polymers

A. Chapiro (Centre National de la Recherche Scientifique, [CNRS], Thiais, France) reviewed the general field. The areas of current industrial interest are polymerization, grafting, degradation, crosslinking, the curing of coatings, and sterilization. The applied radiation chemistry of these and related processes was discussed by M. Dole (Baylor Univ.). Two invited papers were concerned with radiation processing including polymers (Z.T. Ma, Shanghai Univ. of Science and Technology and N-Y. Lin, Institute of Nuclear Research, Academie Sinica, Shanghai, People's Republic of China [PRC]).

Lectures concerning the effects of high energy radiation specifically on polyethylene were given by B.J. Lyons (Raychem, Menlo Park, CA), A. Keller (Univ. of Bristol), and J.C. Randall (Phillips Petroleum Co., Bartlesville OK) with J. Silverman (Univ. of Maryland). P.G. De Gennes (College de France, Paris) treated the theoretical aspects of the effects of shear on polymer-polymer reaction rates. Low energy (<300 kV) electron processing developments were discussed by S.V. Nablo (Energy Sciences Inc., Woburn MA). The preparation of blood-compatible polymers for biomedical applications by radiation grafting was reviewed by A.S. Hoffman (Univ. of Washington). Finally, recent advances in the stabilization of polypropylene were described by J.L. Williams (Becton Dickinson Co., Research Triangle Park, NC). Several contributed papers and posters dealt with polymerization, grafting, and degradation.

Polymerization. The advantages of using radiation to initiate polymerization were outlined by Chapiro. The initiation step is temperature independent, making it possible to cover broad ranges of practical conditions leading to better control of the molecular weights of the product. Furthermore, the resulting polymers are not contaminated with residual initiator fragments found in chemically synthesized materials. The purer polymers could be of interest for use as high frequency insulators or as biomedical materials, for example.

In spite of these and other advantages, only one truly industrial-scale production of radiation-synthesized polymers has been announced: very high molecular weight water soluble polymers and copolymers of acrylamide (Neutron Products Inc. Dickerson, MD). Z.T. Ma indicated that the "middle scale" production of high molecular weight polyacrylamide using cobalt 60 radiation had begun in the PRC. He also noted that "trial" productions of polychlorotrifluorethylene and its copolymer with ethylene and acrylic acid-butyl acrylate copolymers were under way.

A.P. Shvedchikov (Institute of Chemical Physics, USSR Academy of Sciences, Moscow) reported on studies of the production of fluoro-oligomers and

telomers by the gamma-radiation-initiated polymerization of trifluoromethyl propylene and perfluoropropylene in the presence of telogens. The materials were said to be of potential use in special adhesives and plasticizers. It was felt that there will be other examples of the use of radiation after thorough evaluation of various systems now under study in various laboratories.

Grafting. Grafting is the joining of branches of one polymer, or copolymer, to the backbone of another. The graft copolymers can be conveniently and cleanly synthesized with high energy radiation. No large industrial scale or advanced development stage applications were reported. In his plenary lecture, Chapiro mentioned the industrial scale grafting of acrylic acid to polyethylene and polypropylene in France. The grafted polymers adhere well to aluminum and other metals. For many years in the US, somewhat related grafts, also to fluorinated polymers, have been in production on a small scale as alkaline battery separators; a number of similar systems are under intensive development in France, Japan, the UK, and elsewhere.

Acrylic acid grafted to polyethylene and polypropylene for battery separators and for zinc-based alkaline batteries was described by N.-Y. Lin and Z.T. Ma, respectively. Radiation grafts to polypropylene nonwoven fabrics have also been produced in small scale batches. Laminated tapes prepared from permselective grafted polyethylene films laminated to one or two layers of cellulose triacetate are in the preliminary pilot plant stage for use as battery separators. A number of fundamental studies of the grafting process itself were briefly described by Z.T. Ma.

G. Ellinghorst (Univ. of Cologne) also discussed radiation grafting to polymer films for separation membranes. Films studied included polyvinyl fluoride, polyvinylidene fluoride, ethylene-tetrafluorethylene copolymer, and polypropylene. Grafting monomers included N-vinyl pyrrolidone, vinyl acetate, styrene, acrylic and methacrylic acids, 4-vinyl pyridine, dimethylamino ethyl methacrylate, and 1-vinyl imidazole. Grafting conditions were examined to achieve uniformity across the film thickness. The resulting membranes were characterized by microscopy and electrical resistance, when appropriate, and the permselectivity was evaluated. The suitability of the grafted films for practical separations was briefly discussed in light of preliminary laboratory experiments.

K. Hayakawa (Government Industrial Research Institute, Nagoya, Japan) described the preparation of radiation resistant polyethylene films by grafting acenapthylene. J.L. Garnett (Univ. of New South Wales) presented new work on the enhancement of grafting yields by the use of additives, including mineral acid and multifunctional vinyl monomers. In his plenary lecture, Dole discussed Garnett's work and some new applications, such as the improvement of pigskin leathers. An invited paper by A.S. Hoffman (Univ. of Washington) read by V.T. Stannett reviewed the preparation of blood-compatible polymers by the surface grafting of hydrogels. Hydroxyethyl methacrylate alone and with ethyl methacrylate were the principal monomer systems studied. Polyurethanes, polyethylene, and silicone rubber were selected as substrates. Both in vitro and in vivo tests were conducted. Hydrogels with water contents of 15 to 85% tend to absorb fewer protein molecules and to desorb them more rapidly in vitro. They formed thrombi but adhered less in vivo. However, more rapid formation and greater volumes of platelet microemboli were found with ex vivo femoral baboon shunts. With water contents below 10%, there was an unexpected minimum in platelet consumption. The minimum appeared to be related more to the polymer composition than to the actual amount of water sorbed. The work by Hoffman and his colleagues suggests that special radiation-grafted compositions could be selected to meet specific biological needs.

Degradation. Certain polymers, such as polyisobutylene, cellulosics, and tetrafluorethylene, undergo chain scission--i.e., degradation--when exposed to high energy radiation. Chapiro pointed out that the process may be used to advantage and sometimes is practiced commercially. Polytetrafluoroethylene, for example, can be radiation degraded to form low molecular weight lubricant grades. Some recent research on the mechanism of the degradation was described by N.-Y. Lin. In air, peroxy radicals appeared to be the dominant active component, as shown by electron spin resonance studies.

Several papers were presented on the use of radiation to treat cellulose before hydrolytic or enzymatic breakdown to glucose and eventual conversion to alcohol. A.M. Dela Rosa (Philippines Atomic Energy Commission) showed that gamma irradiated agricultural cellulose wastes gave higher yields of reducing sugars on hydrolysis than did nonirradiated samples. K. Kojima (Sumitomo

Electric Co., Japan) carried out somewhat similar studies but with electron beam irradiation and enzymatic hydrolysis. Significant advantages included easier comminution, easier removal of lignin, and readier hydrolysis by enzymes.

A.S. Klimentov et al. (All Union Scientific Research Institute of Vegetable Raw Material Hydrolysis, USSR) described large scale experiments on the radiation of wood sawdust using electron accelerators; the fraction of easily hydrolyzed polysaccharides was increased, and the products were improved materials for animal feed. The same group studied the effects of electron beam irradiation with doses of 0.5 to 2.0 mrads on nutritive media. The quality of the media was improved because of sterilization and the destruction of inhibitors of yeast growth.

R.L. Cough and K.T. Gillen (Sandia National Laboratories) discussed the radiation-induced degradation of polyvinyl chloride and ethylene-propylene rubber cable coverings at large doses for use in nuclear power plants. Doses up to 200 mrads were studied, and commercial materials were used. Complex and inhomogeneous effects were observed--effects not readily explainable. Further work is in progress.

The rapidly growing use of radiation to sterilize polymers for biomedical applications has led to attempts to stabilize certain polymers--especially polypropylene--against degradation. J.L. Williams and T.S. Dunn (Becton Dickinson Co., Research Triangle Park, NC) reviewed the subject and discussed new formulations of polypropylene to give adequate radiation resistance. The importance of the continued degradation after removal from the radiation source was stressed. The use of low molecular weight "mobilizers" which accelerated the disappearance of trapped radicals, plus effective stabilizers led to an essentially stable product. Differences between the use of electron beam and gamma radiation were also discussed. Although the elementary kinetic events are similar, there are differences in the mechanical properties of the irradiated polymers. These differences are not consistent, however, and depend on the sample size, dimension, and the formulation used.

Crosslinking

The crosslinking of high polymers with high energy radiation is of fundamental interest and dominates the industrial applications of radiation and polymers.

Fundamental Aspects. Radiation crosslinking was discovered in 1948 with polyethylene, which has remained the model polymer for mechanistic studies and industrial applications. Thirty-five years later, the mechanism of crosslinking is still disputed; the effects of crystallinity and morphology on crosslinking yields and distribution are not clear. New data were presented by Dole on linear low density polyethylene quenched and annealed (densities 0.9175 and 0.9225, respectively). The G values (number of events per 100 eV of absorbed energy) for crosslinking in vacuum at room temperature were 2.80 and 2.52. A modified form of the Charlsby-Pinner equation--itself somewhat controversial--was used for the determination.

The effects of crystallinity and the mechanism of the crosslinking reaction were discussed in papers by A. Keller (Univ. of Bristol, UK); B.J. Lyons (Raychem Inc., Menlo Park, CA); J. Silverman (Univ. of Maryland), and J.C. Randall (Phillips Petroleum Co. Bartlesville, OK). These papers were followed by an extensive discussion among the delegates and speakers. Keller reviewed effects of crystallinity and chain folding on the radiation crosslinking of polyethylene. A major influence of morphology was demonstrated, including nonrandomness in the crosslinking process. Extension of the work to paraffin crystals revealed a previously unsuspected mobility of the free radicals in the crystal lattice, leading to phase segregation of the crosslinked species. Other topics discussed by Keller included the effects of morphology on chain scission and nuclear magnetic resonance (NMR) methods of directly measuring crosslinks.

Lyons reviewed his work on the radiation crosslinking of high and linear low density polyethylenes. He demonstrated the significant differences between commercial and fractionated polyethylenes. Low molecular weight material contains most of the terminal vinyl groups and tends to segregate during crystallization. The great importance of reactions of alkyl radicals and hydrogen atoms with the vinyl end groups was stressed. These lead to end linking reactions that increase the weight average more than the number average molecular weights, producing wide molecular weight distributions. The resulting complications affect, among other things, the measurement of crosslinking by sol-gel analysis and the elastic moduli of the samples. It is generally agreed that the crosslinking reaction takes place in the

noncrystalline regions. However, the free radical, or other active, precursors are formed throughout the polymer by the radiation. It is still not clear whether those formed in the crystal lattice migrate to the amorphous parts by a hopping mechanism, which may or may not involve reactions of hydrogen with alkyl radicals, or have another fate.

One highlight of the meeting was a fundamental contribution to the actual radiation chemistry of polyethylene. J. Silverman (Univ. of Maryland) pointed out the importance of the much-neglected possibility of the end linking reaction in irradiated polyethylene (Figure 1).

The reaction leads to the formation of long chain branches (Y-links). The high concentration of vinyl groups in the amorphous region makes this reaction far more likely than the recombination of the secondary alkyl radicals to form a crosslink. At the meeting, new high resolution NMR data presented by J. Randall showed clearly the presence of the Y-links but failed to disclose the existence of the crosslinks. Nevertheless, Silverman regards crosslink formation as the most likely fate of the ultimate disappearance of the secondary radicals.

Remarks by P.G. de Gennes (College de France, Paris) support the suspicion that immobilization of the crosslinks in long-chain polyethylene renders them undetectable by NMR; the same links should be detectable, however, for M_n < 10,000. In addition, Silverman advanced the possibility of β-cleavage at room temperature of a crystalline chain fold containing a radical; this would produce a primary radical and a vinyl end group. A more common explanation of the low molecular weight products observed in irradiated polyethylene by gel permeation chromatography and NMR is main-chain scission to produce two primary radicals. P.G. de Gennes presented a new theoretical treatment of the effect of shear on polymer-polymer reaction rates. The now well-known reptation approach was used; entangled and nonentangled coils were considered. Such reactions are related to crosslinking reactions in the melt and will be extended to solutions. More experimental verification of the results of the derivations are needed, but the approach has already shown a better match with actual results.

Practical Applications. Industrial applications of radiation-induced crosslinking reactions were briefly summarized by Chapiro and Dole in their plenary lectures. The applications include wire and cable coatings and plastic tubing for hot water pipes; improved high temperature resistance is one of the main objectives. The so-called memory effect is shown when crosslinked semicrystalline polymers--raised above their melting point, stretched, and cooled in the stretched condition--revert to their original dimensions on reheating. The effect has widespread commercial application as heat shrinkable tubing, film, splices, and other, more sophisticated, devices.

Snyder reviewed the large scale application of radiation to rubber for tire manufacture. Selective tire components are irradiated and used to confer greater initial "green" strength, which contributes greatly to the uniform construction of superior tires. Polyethylene foam is also produced in film, sheeting, and tapes by radiation crosslinking before the foaming itself. These applications involve crosslinking essentially throughout the structure, but surface crosslinking also can help provide abrasion resistance, prevent mutual adhesion on heating, and improve the resistance of polyethylene to degradation or cyclic flexing in seawater. Dole also discussed the use of various organic and inorganic additives to improve crosslinking or actually

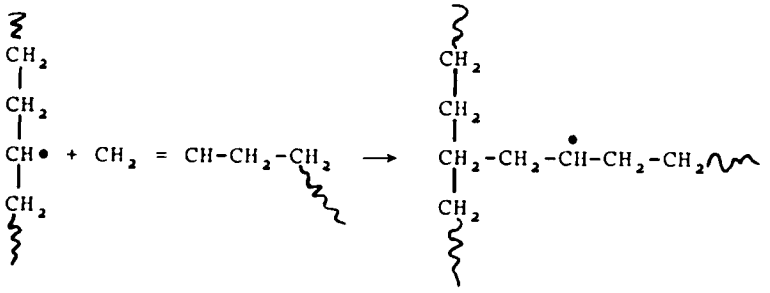

Figure 1. Linking reaction in irradiation polyethylene.

impart it in the case of polyvinyl chloride. The additives have found wide use in the wire and cable coating industry--especially for telecommunication wires and in nuclear power plants.

Three contributions indicated current trends in the PRC. Z.T. Ma said that crosslinking of polyethylene film and tubing, of silicon rubber, and of fluoropolymers are in the small batch production stage. The crosslinked fluoropolymers, apparently made by the addition of vinyl monomers, were reported to have good antisplit and high temperature resistance, and to be used in a special but undescribed technology. A contribution from Peking Normal Univ. (R. Zhou) described the use of a 3- to 5-MeV linear accelerator for producing polyethylene foam sheets of 0.8- to 4.0-mm thickness. The relationships between dose and gel content and elongation, and between percent gel and cavity size have been determined for particular materials and conditions. A poster by W. Chen et al. (Peking Normal Univ.) described the heat shrinking versus dose curves for polyethylene under different sequences of treatment. It was found that a low preirradiation dose followed by preheating, stretching, and irradiation gave the maximum shrink compared with simply stretching and irradiating.

I. Uda (Sumitomo Electric Industries, Japan) discussed the increasing use of flame-resistant irradiated polyethylene and polyvinyl chloride for wire coatings in electronic equipment and the internal wiring in automobiles. V. Markovic (Boris Kidric Institute of Nuclear Sciences, Belgrade) has determined the gel-dose curves for four varieties of linear low-density polyethylene together with their thermal and viscoelastic properties. O. Gal, from the same institute, reported on the effects of various kinds of antioxidants on the thermoxidative stability of low density polyethylene in air. The hindered phenolic antioxidant was shown to be superior. Gal's study is being combined with one on antioxidants' effects on the gel-dose behavior.

F. Ranogajec (R. Boskovic Institute, Zagreb) described the use of different polyfunctional monomers at 30 parts per hundred in polyvinyl chloride for radiation crosslinking. Gel-dose plots indicated that different monomers showed widely different results. Ethylene glycol dimethacrylate gave the highest gel contents, but the choice of monomer depends on the price, dose, and product specification. Ranogajec described work showing that plasticized radiation crosslinked polyvinyl chloride pipes had much greater pressure, mechanical, heat, and chemical resistance. L. Wiesner (Beta-Gamma-Service Co., Odenthal, West Germany) discussed in general terms the developing use of gamma and electron beam irradiation with molded plastic parts. Considerable expansion of this area is anticipated over the next several years.

H. Kinuta (Sumitomo Electric Industries) described a new method of using electron beams for wire and cable irradiation. The scanning width is divided into two or more parts by a shutter. In this way the dose rate of each part can be controlled. Otherwise the complete accelerator needs to be stopped--e.g., for changing reels. The method was shown to give satisfactory mean and standard deviations for the gel fraction for both polyethylene and polyvinyl chloride insulated wires. It is claimed that a 30% increase in efficiency is obtained.

R. Bäuerleun (Simens A.G., Erlangen) used the elastic modulus measurements in a rubber elastic sheet of crosslinked thermoplastic materials to obtain qualitative and quantitative information concerning the circumferential distribution of crosslinks. Two papers by W. Pekala (Technical Univ. Lodz) described the relationships between dose and gel formation in the gamma irradiation of aqueous acrylamide solutions and the properties of the resulting gels. The gels can be used for sustained drug delivery if they are coated on polyurethane foils with the drug on the opposite side. The products were judged to be clinically acceptable and useful for wound dressings.

S.V. Nablo (Energy Sciences Inc., Woburn, MA) described several applications of the use of low energy (< 300 kV) electron beams for curing (crosslinking) 100% reactive coatings. Among the applications are high gloss base coats for the vacuum metallization of paper and nonwoven fabrics, including transfer coating of the metal. Laminating resins and adhesives were being cured for wood and other surfaces. Metal parts were being coated by Volkswagen and Japan Steel Co. Many other applications were also briefly mentioned.

T. Ohta (Hitachi Chemical Co., Japan) described the use of ultraviolet (UV) and electron beam (EB) radiation for curing pressure sensitive adhesives based on acrylic oligomers. The peel strength at all rates of peeling was found to be higher with EB curing at the same double bond concentrations in the formulation. UV appeared to lead to more densely crosslinked cures than EB. P. Holl (Polymer-Physik Co., Tübingen)

discussed the use of EB for curing paints on shaped parts, including automobile wheels, bumpers, dashboards, and electronic equipment housings. New techniques for removing air or minimizing the effects of oxygen were described but not detailed. Z.T. Ma included in his invited paper a short discussion of work on the EB curing of a number of acrylic oligomer-reactive monomer coatings for wood surfaces and tin cans. Fundamental studies related the rate of curing with gel content and the degree of unsaturation.

The full proceedings, including presentations on subjects other than high polymers, will be published in special issues of Radiation Physics and Chemistry (Pergamon Press).

V.T. Stannett

THE SEVENTH INTERNATIONAL SYMPOSIUM ON GAS KINETICS

The Seventh International Symposium on Gas Kinetics, sponsored by the Gas Kinetics Group of the Royal Society of Chemistry of Great Britain and the Deutsche Bunsengesellschaft für Physicalische Chemie, was held in Göttingen, West Germany, 23 through 27 August 1982. Nearly 300 participants attended.

Dynamics of Reactions

The technical program opened with a session on the dynamics of reactions and potential energy surfaces. E. Pollak (Department of Chemical Physics, Weizmann Institute, Rehovot, Israel) presented recent calculations addressing the discrepancy in experimental and theoretical rates of hydrogen exchange with the hydrogen molecule. Using a three-dimensional generalization of a semiclassical adiabatic transition state theory, he calculated the height of the barrier on the v = 1 adiabatic surface in the entrance channel. Pollack suggested that a recalculation of the surface in the barrier region would yield a convergence of theoretical and experimental rates. In a fluorescence study, D.G. Imre and coworkers (Massachussetts Institute of Technology, Cambridge, MA) studied the dynamics of the upper potential surface in the dissociation of the ozone molecule.

The highlight of the session was the Polanyi Memorial Lecture given by Prof. D. Herschbach (Chemistry Department, Harvard Univ., Cambridge, MA), recipient of the Polyani Medal this year. Herschbach spoke on various topics, including the ESR of matrix-isolated K^+Cl^- H, chemionization on alkali surfaces, extremely inelastic energy transfer, and a new approach to electronic structure and molecular dynamics based on the theory of quarks. Taking the dimension of space, D, as a variable, Herschbach calculated quantities such as the ground state energy for two-electron atoms as a function of D. His approach is efficient with computer time and can be tried with any dynamical problem. In particular, it may be useful in the theory of phase transitions.

Biomolecular Reactions

The two sessions on elementary bimolecular reactions included a talk by J.P. Simmons (Chemistry Department, Univ. of Nottingham, UK) on metastable rare gas atom reactions with rare gas halides. Simmons concluded that Rydberg states rather than a "harpooning" process were involved. A great deal of interest was also shown in the paper by F. Kaufman (Department of Chemistry at the Univ. of Pittsburgh, PA), who studied the rates and product channels of HO_2 reactions, and particularly in the negative temperature dependence for such reactions. J.V. Michael (Brookhaven National Laboratory, US) reported on the absolute rate constants for the reactions of OH radicals with acetaldehyde. The observed negative temperature dependence implies adduct formation, and the lack of pressure dependence may mean that there is a forward dissociation process that is faster than the back process.

The reaction of OH and ethylene oxide was studied by R. Zellner and colleagues (Institut für Physicalische Chemie, Universitat Göttingen, West Germany). Considerable interest was expressed in the larger than expected stability of the cyclic C_2H_3O radical. P. Gray and coworkers (School of Chemistry, Univ. of Leeds, UK) have developed a pulsed flow-tube method for directly measuring the diffusion coefficients of atoms and free radicals in gases. In addition to the results for H atoms in various gases, they also reported a novel observation of a chromatographic effect of highly reactive species under their experimental conditions.

G. Tyndall (Univ. of Cambridge, UK) gave a thought-provoking report on the kinetics of the HO_2 + HO_2 reaction. Although calculations completely fitted

the system with a common intermediate, when extended to the deuterated case the Rice-Ramsperger-Kassel-Marcus (RRKM) model could not explain the pressure dependence. An RRKM model would predict a steep pressure dependence, whereas approximately the same dependence was found.

Unimolecular Reactions

The session on unimolecular reactions and energy transfer created one of the main (albeit friendly) controversies of the conference. With his work on azulene, J. Barker (SRI International, Menlo Park, CA) found collisional energy transfer with all colliders to be energy dependent. Jurgen Troe measured an energy loss profile for hot toluene molecules. The average energy lost per collision is the slope of the energy loss curve, and the experiments showed it to be linear, corresponding to a constant ΔE_d.

Ion-Molecule Reactions

In the session on ion-molecule reactions, K.R. Jennings (Univ. of Warwick, Coventry, UK) presented the results of his kinetic and thermodynamic studies on termolecular ion-molecule reactions. The author attempted to separate the effects of loss of ions by reaction and diffusion. Of particular interest to the audience was the temperature of such reactions.

Laser-Induced Processes

In the session on laser-induced processes, a report by C.E. Geosling (Naval Research Laboratory, Washington, DC) on site selective multiphoton infrared photochemistry in a large molecule was received with interest. The author observed a selective elimination reaction on the irradiated end of a long, semideuterated hydrocarbon. J. Pfab (Heriot-Watt Univ., Edinburgh, UK) gave a talk on the laser-induced fluorescence of nitrosyl cyanide and several larger C-nitroso-compound fragments.

Radical Combination Reactions

In the session on radical combination reactions, D. Gutman (Illinois Institute of Technology Chicago, IL) presented a new method for studying polyatomic free radicals using a pulsed CO_2 TEA laser and a photoionization mass spectrometer. The author reported on the real-time monitoring of acetyl radical recombinations.

Complex Processes

The final session of the conference addressed complex processes and concluded with a paper by J.E. Dove of the Univ. of Göttingen on dissociation rates behind interstellar shock waves. Dove calculated "fall-off" curves for the dissociation of molecular hydrogen in an interstellar molecular cloud. Even though it was the last paper of the conference, the discussion, as had happened many times in the preceding days, continued in the corridor.

The conference organizers should be credited for a very successful program. In the closing remarks of the conference, session chairman M.J. Pilling (Univ. of Oxford, UK) stated that the quality of papers presented was evidenced by the fact that the session attendance had not waned from the first to the last paper.

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COMPUTER SCIENCES

EXPERT SYSTEMS HELP PRESERVE SPECIALIZED KNOWLEDGE

Prof. D. Michie, head of the machine Intelligence Unit at the Univ. of Edinburgh, is one of the founders of the field of artificial intelligence. Recently, Michie was visited by Dr. Robert Quattrone of the U.S. Army Construction Engineering Research Laboratory; Dr. F. Rothwarf and George Sokol of the U.S. Army Research, Development, and Standardization Group UK; and Major J. Gowan of the European Office of Aerospace Research and Development. This article describes the nature of expert systems and the work of Michie, and suggests a possible application to a procedure for material corrosion analysis developed by Prof. M. Pourbaix of the Univ. of Brussels.

Michie has trained many students who have gone on to play influential roles in American universities, where some of the most important contributions to the field have been made. He divides his time between the UK and the US, where he serves as adjunct professor of computer science at the Univ. of Illinois. Michie has a consulting firm called Intelligent Terminals Ltd., (ITL) in Britain, which has an affiliate, ITLA, in the US. Increasingly, Michie has become interested in "expert systems." These are data processing

systems but differ from the major types, management information systems, operational automation systems, and decision support systems.

Data Processing Systems

A management information system (MIS), for example, stores in a computer information about the operations of a company or an agency. Organized files are maintained in the computer, and new information is added to data in the files. The system can produce a wide variety of tabular and graphic reports, which can show current status or cumulative trends. The reports, available for analysis and review by management officials, may involve the application of statistical and analytical tools that are also stored in the computer.

MISs that have been refined to handle actual operational duties are called operational automation systems (OAS). Often the data in the computer's files can be used to initiate and complete other actions. If the rules and procedures for the actions are reasonably straightforward and well codified, the computer can store the procedures and the data; when new data indicate that certain thresholds have been reached, the necessary action is taken automatically. In supply systems, for example, cumulative records of consumption trigger an order for new supplies. Based on the rate of consumption, the computer can generate reorder forms that show automatically calculated quantities and required delivery dates.

Recently, decision support systems (DSSs) and expert systems have been developed for use when the data are uncertain and the rules incomplete. Unlike an MIS, a DSS is intended to cope with a situation in which the decisions to be made are totally new and have not been made before. Like the MIS and OAS, the DSS has a large capacity for data storage, and it usually has a very flexible relational data base that can be reorganized quickly in various ways.

But the strength of the DSS is its variety of powerful analytical-modeling and graphic tools and its rich interactive display capability. The manager or specialist can work with the display to examine new combinations of data, to project the probable results of various actions, and to develop a much more complete or detailed picture of situations and options before making final decisions.

Expert Systems

In expert systems, Michie and his peers have gone a step further. Michie finds that most complex human undertakings are rule based, but the rule book is often extremely long and exists only in unassembled form. This is true whether the process is playing games (e.g., chess), running a company, or performing technical research. Michie estimates that a grand master chess player has a memory bank of about 50,000 rules and that he invokes many of them unconsciously--or at least cannot articulate the rules as he uses them.

An expert system draws on a data base of specialized information (or "rules") and applies it to particular situations. Such a system can offer much greater speed in retrieving data, can apply the rules that have been stored, can perform indicated analyses, and can present conclusions. Perhaps even more important is that the automated expert system is not limited to the knowledge of one individual, but it can contain and combine the rules and their variations as known to an entire community of experts.

Michie indicated that the Digital Equipment Corporation (DEC) has been especially active in building expert systems. For example, in conjunction with Carnegie-Mellon Univ., DEC has built a technical sales system called R-1 and a sales administration system called EXSEL. According to Michie, both systems have been more successful than field sales personnel in identifying the preferred solutions to particular sales problems.

Powerful data-base techniques have been important in making expert systems feasible. Relational data bases have already shown their value in programming. However, present data-base-retrieval methods operate strictly by extracting data that have specific relationships to some other data or that occur in a specified place in the file. Michie described the work of J. Robinson (Syracuse Univ.) who has developed LOGLISP, a powerful tool based on the LISP list processing language.

According to Michie, LOGLISP combines the retrieval function with a logical capability and can respond to retrieval questions when the answer must be reasoned from a combination of data in the bank and logical rules. K. Clark (Imperial College, London) has developed a modest economical software package called MICROPROLOG that performs a similar function. MICROPROLOG can operate on a microcomputer; LOGLISP, however, requires a large computer.

Expert systems can be valuable even if the knowledge represents only that of one highly qualified person. H. Polpe (Univ. of Pittsburgh) is building an

interactive expert system based on the medical knowledge of Pittsburgh's Dr. J.D. Myers, a noted internist. The purpose of the system, called CADUCEUS, is to preserve the knowledge of one great physician; thus, the information can be referred to, used, and augmented even after the man has stopped practicing and teaching.

Michie believes that the feasibility of modest expert systems has been proved and that the development of more ambitious systems can be undertaken with confidence.

Expert System for Corrosion Analysis

One possible application for corrosion analysis may aid in the design of metal products. Prof. M. Pourbaix of the Univ. of Brussels has developed a compendium on corrosion for many useful metals. In the Atlas Of Electrochemical Equilibria in Aqueous Solutions (Houston, TX: National Association of Corrosion Engineers, 1974) Pourbaix presents a graphical technique that quickly displays regions on an electric potential/pH diagram--regions in which a given metal may be vulnerable or immune to corrosion. Electrochemical reactions of an element in an aqueous medium near an electrode are quite important. Such reactions can be used to predict the equilibrium states of all possible reactions of the element, its ions, and its solid and gaseous compounds in the presence of water.

For each of the 90 elements in the atlas, the Pourbaix diagram is fundamentally a plot of electrical potential (E) against hydrogen ion concentration (pH). For example, the diagram for tungsten-water in Figure 1 indicates that pH generally ranges from -2 (extreme acidity) to 16 (extreme alkalinity). A pH value of 7 represents a neutral solution. Figure 1 is divided into three regions: oxidation, stability, and reduction. For a specific metal, a graph on the same scale can be

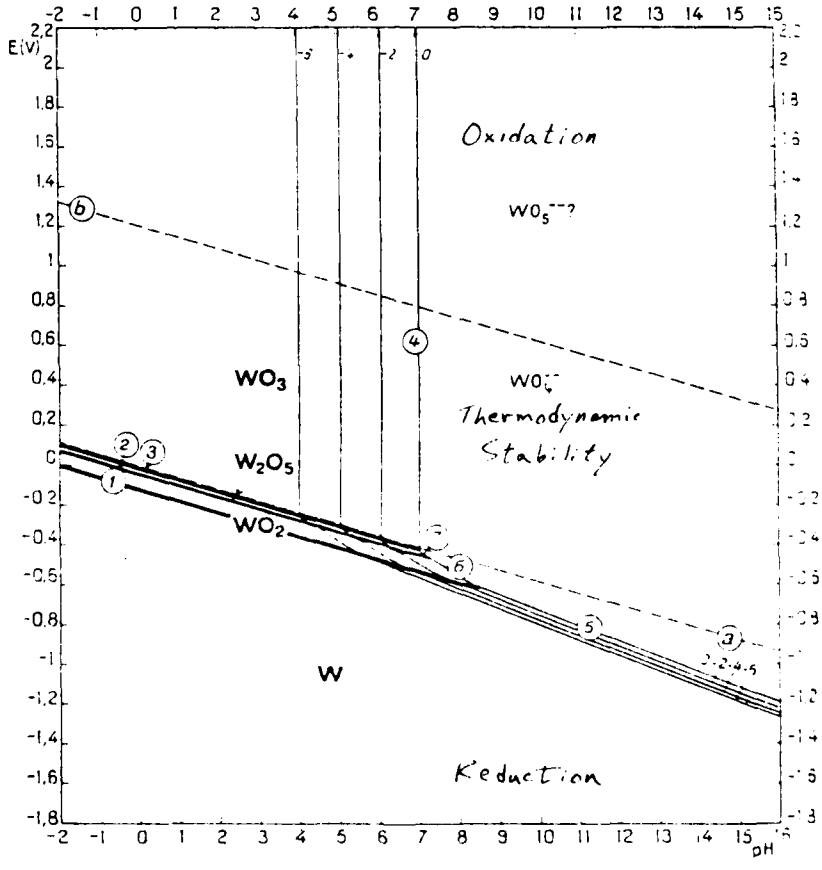

Figure 1. Potential-pH equilibrium diagram for the system tungsten-water at 25°C.

created to indicate boundaries separating regions of passivations, corrosion, and immunity; Figure 2 shows a sample plot for tungsten. Superposing Figures 1 and 2 conveniently indicates areas of metal that are not vulnerable to corrosion. Furthermore, if an alloy is under study, Pourbaix has shown that simply superposing such graphs for all component metals will produce a composite chart revealing the residual area of "no vulnerability."

Pourbaix's diagrams offer a powerful and convenient tool for use in the design of metal products. Corrosion damage to metal structures and equipment now costs the U.S. Department of Defense billions of dollars annually; there has been interest in using Pourbaix's techniques to control such expenses. In fact, the U.S. Air Force's European Office of Aerospace Research and Development has funded an English translation of Pourbaix's atlas.

It must be emphasized that the diagrams describe "pure" situations. In actual alloys, the exact composition is not always known. Therefore, successful analyses with the diagrams require that the analyst use extensive experience and knowledge.

In construction engineering practice today, the potential contribution of Pourbaix's diagrams is largely unrealized. The typical civil engineer or construction engineer does not use the diagrams and, indeed, may not even know about them. An engineer who does try to use the diagrams might lack the training and qualifications of an electrochemist or metallurgist. The skills of such specialists are needed for interpreting the diagrams and adjusting the results to allow for the impurities or uncertainties of actual samples.

Pourbaix's atlas with its compendium of diagrams does not deal with corrosion phenomena in the presence of a gaseous phase. But Pourbaix has been studying chemical and electrochemical equilibria in the high temperature region up to 6000°K. He wants to provide a compendium of his knowledge on high temperature gaseous corrosion--a work similar his published atlas. Such a compendium could help solve problems in the design of corrosion-resistant gun barrels, the passivation of semiconductor surfaces, and the design of corrosion-resistant mirrors for high energy lasers.

It would be very useful to preserve Pourbaix's approaches, thinking processes, and "rules of thumb" for other researchers who might continue his work. Therefore, an expert system on corrosion

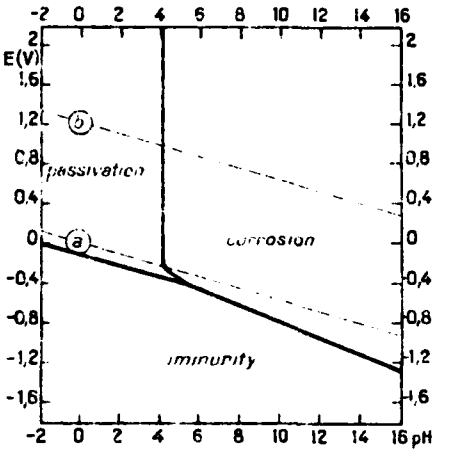

Figure 2. Theoretical conditions of corrosion, immunity, and passivation of tungsten at 25°C.

is being considered by the Univ. of Brussels. The system would incorporate Pourbaix's methods of solving corrosion problems.

Such expert knowledge would also be valuable to engineers who want to apply the Pourbaix diagrams to specific designs. A structural engineer with access to the system would have the specialized information needed to help prevent corrosion in metals.

Michie estimates that it will take a 3-year program to produce the expert system. The first year would be devoted to developing and codifying the domain description and starting the associated knowledge base. Knowledge base building would continue in the second year, with an initial test capability ready by the end of the second year. The third year would be devoted to operational use, refinement, debugging, and documentation.

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ROBOTICS RESEARCH AT IRISA

The two principal areas of research in robotics at Institut de Recherche en Informatique et Systèmes Aléatoires (IRISA, Rennes, France) are in sensing the environment and controlling the robot. This article is based on discussions with Bernard Espiau at IRISA on 16 November 1982.

Sensing of the Environment

At each instant, the robot must identify two types of objects:

- An obstacle--any object preventing the completion of a task.
- A target--any object upon which the robot must act instantly to complete a task.

The global environment includes all obstacles and targets at a given instant. The local environment is the portion of the global environment near the movable parts of the robot manipulator. In a robot's system of external perception, the measures of proximity concern only the local environment.

Generally the entire local environment is not sensed. The part observed is often reduced to a certain area around the gripper, which can be considered autonomous--at least with regard to the sensing system's perception of the interaction between the gripper and objects.

The perception of the local environment results from its nearness. A proximity sensor gives information about one of the following:

1. An obstacle or a target in the observed part of the local environment. The sensor should determine characteristics such as the state of the surface, the color, and the geometric configuration.

2. The relation between the object and the robot. This includes the distance of the object from the robot, the nature of any relative movement, and any specific reaction of the sensor with respect to the object.

In general, the local environment of the gripper consists of three zones: first, a repulsive external zone requiring avoidance of an obstacle. Second, an attractive external zone, generally near the extremities of the fingers of the gripper. The sensors should help put the robot in position to grasp the object. This requires finding zones on the object suitable for grasping. Third, an internal zone to facilitate continuous movement to contact the object with the gripper. The sensors and grippers are a local perception structure that must be associated with processing algorithms corresponding to the functions for analysis and control required by the applications.

For analysis, the processing of information from the sensors is of the open loop type, with reaction by the manipulator only upon control from a higher decision level. The three aspects dealt with at IRISA are, in increasing order of complexity: detection, measurement of distance, and extraction of shape parameters, for which infrared sensors are used. There has been some success with measuring distance by filtering algorithms. Simultaneously, the special characteristics of sensors developed at Rennes can be used to estimate the retro-diffusion power and distance of a target.

Taking account of information near the level of control can be done in two ways:

1. By following planned trajectories or classes of linked movements in accordance with systematic or heuristic procedures. For example, if associated with a technique for determining shape, the procedure permits the finding and classifying of grasping zones. The information also can be incorporated in classic algorithms of movement in the presence of obstacles.

2. By constructing a local control loop with constant feedback of information from the sensors. One must study a true loop's effects on the system's dynamics--the stability, for example.

At IRISA, emphasis has been mainly on local control loops. The approach can be described as follows: assume a target that can be gripped and a grasping arm in an area with obstacles. The proximity sensors are placed in the pincers to permit centering, straightening, and movement. An observation site, CI; a direction of observation, DI; a signal, SI (combination of elementary signals); an action site, XI; and a direction of action, OI, are associated with each sensor or group of sensors. Between two successive times, KT and (K+1)T, the desired elementary action is to move the point XI toward the point XI + WIOI, where WI is a function of SI. The specification of XI, OI, FI, and SI determine the character of each elementary function (repulsion or attraction), as well as the dynamics of the system. The incremental control required is the combination of translation and rotation needed between KT and (K+1)T to satisfy all constraints required by the desired elementary actions.

In most cases an explicit solution can be found with little computation. Using signals from optical sensors directly furnishes a repulsion corresponding to a Newtonian potential, and continuity with gripping is assured by the choice of certain combinations (CI, DI, XI, OI, WI). For bi-digital or tri-digital grippers, the choice results naturally from the geometry adopted for the fingers and the contact sensors.

Control of Robots

To improve the accuracy of manipulators, controllers must be designed to allow reliable, high velocity movement.

Moving an effector to a final position with a given dynamical behavior, or tracking a desired trajectory are classical control problems. Difficulties arise at high velocity when the required behavior must be independent of parameters such as the payload and the location of the effector. If the control is handled by a fixed linear monodimensional servo system on each joint, the desired accuracy generally cannot be achieved for high velocity motions.

An alternative is to derive dynamic control algorithms that take into account coupling and nonlinearities by using a dynamic model of the manipulator including gravity, inertial, centrifugal, and coriolis forces and torques. One approach is to precompensate for nonlinear terms using a theoretical model with a feed forward loop. In case the model is precisely known, a linear decoupled feedback may be enough to assign the dynamics of the closed-loop system. Control systems using a dynamic model of the manipulator have drawbacks: real-time computation is costly, accuracy of the system may be degraded by modelling errors, and adaptation to variations and drifts is not certain even if the parameters of the basic model have been well defined.

The objective of the study at IRISA was to test several alternatives to the classic technique. A direct adaptive control algorithm was applied in one case and an indirect adaptive control in the other. The algorithms have been studied for linear systems. Modelling a manipulator joint by a stationary linear system would be satisfactory for small and slow motions. However, for large and fast motions a linear model of the joint was considered nonstationary. The variation of the model coefficients comes from nonlinearities and coupling terms. To track the nonstationary characteristics of the model, identification algorithms with gains never decreasing to zero were used. The working hypothesis is that variations of the model are slow compared with the dynamics of the adaptation.

Simulation results were obtained by applying direct and indirect adaptive control algorithms to each of two manipulator systems. The first manipulator was a three-link cylindrical coordinate type. The second was a three-link, three-joint (two rotations and one translation) manipulator.

Adaptive techniques are inconvenient primarily because they were developed for linear systems, but robots are nonlinear systems. Therefore, it is difficult to analyze precisely and theoretically the results of such controls.

Thus, research at IRISA is oriented toward "robust" control techniques, which are nonlinear (variable gain) with reference models. Simulation tests will soon be implanted on a fast industrial robot.

J.F. Blackburn

ROBOTICS RESEARCH AT LABORATOIRE D'AUTOMATIQUE ET D'ANALYSE DES SYSTEMES

At Laboratoire d'Automatique et d'Analyse des Systemes (LAAS), Toulouse, France, an official program on Automation and Advanced Robotics began in October 1980, although research in robotics was under way as far back as 1977. This article is based on a 19 November 1982 interview in Toulouse with Messrs. G. Giralt, President, Coordination Office, Program of Automation and Advanced Robotics; R. Prajoux, Research Director, Logic of Systems and Robotics; and M. Ghallab, Researcher, Graphics and Pattern Recognition.

Scientific interest in the robotics study is multidisciplinary and includes work in algorithms, artificial intelligence, pattern recognition, command theory, and various aspects of mechanical and electrical engineering. Socioeconomic interests arise from the expected impact of robots on industry.

The research program, supported in part by contracts from France's Ministry of Research and Industry, is organized in the areas of advanced teleoperation, mechanics and technology for robots, general robotics, and flexible workshops. The number of equivalent full-time professionals in automation and advanced robotics research in France is more than 150; 30 are in the group at LAAS.

Autonomous Mobile Robot

A nonspecialized mobile robot called Hilare is equipped with multisensor systems and uses a multilevel computer and decision system. The machine has microprocessors for locomotion control, ultrasonics, camera control, image preprocessing, and communication. Higher level processing of information is by a larger local computer; computers at Paris and Montpelier are back-up. Hilare is intended to serve as an experimental support vehicle.

The perception system for the three-dimensional universe of the robot combines information received from a two-dimensional video and from a laser telemeter giving the depth. Two coordinates of a point can be derived from the tilt of the mirrors used to deflect a laser beam onto the target. The third coordinate is determined by the travel time of the laser beam.

The system must be able to find the position and orientation of obstacles, which are always treated as polyhedrons. The system must also be able to recognize objects in a room, which requires complex pattern recognition.

The video signal from the camera is coded over several levels of grey. From the coded image, the contours of objects and adjacent objects are determined. The information from the camera is transmitted to a higher level of the computer and decision system and combined with the laser range information. The telemeter is coupled to the camera so that their optical axes are in agreement. The entire apparatus is mounted on a turntable on the robot. Commands to the motors used to deflect the laser beam are based on data from the microprocessor associated with image processing (INTEL 8030) or from the higher-level decision center. The number of measurements by the telemeter are reduced through using only information in the zones where a change of direction of a contour is detected; thus corners of an obstacle or object are located.

All obstacles are assumed to be polyhedral and are represented in two dimensions by polygons or parts of polygons. The main objective in path planning is to create a structure composed of polygonal cells and to construct a graph connecting those cells to transform the geometric model into a topological one. The four steps are perception, space structuring, path search, and path execution.

A system to navigate a mobile robot has been written in APL (a programming language) and implemented on an IBM 3033 linked to a 16-bit minicomputer (MITRA 15). The microcomputer is in turn linked to the on-board, five-microcomputer structure (INTEL 8085) controlling the robot's motors and sensors. The system has been tested for many obstacle configurations.

Identification and Localization of Partially Observed Parts

Automatic recognition of mechanical parts is an important application of pattern recognition. Parts overlap and are often partially obscured, so global properties are not always available. One project at LAAS is concerned with identifying and sorting small parts for an automated assembly line. Recognition can be achieved through a correlation-like comparison of a local descriptor, such as curvature, with a reference descriptor calculated during a previous learning phase. The method has limitations when there are many parts. In another approach, the contour lines are presented by a set of syntactic primitives. A contour is represented by appropriately shaped primitives--such as straight lines, arcs, corners, and holes--obtained during a segmentation phase and representing details and rules describing the global structure.

For image processing the sensor is a television camera (National Newvicon WV 1350) with a normal scanning mode. A two-level quantization of the signal is implemented and yields a binary image of the objects. The binary image is then reduced to its contour points. As the image is received, successive lines are processed recursively.

Object segmentation and a test for hole contouring are also direct results of the method. In the absence of noise, a differentiation of the contour into north-south and east-west would allow recognition of a part. However, noise and sensitivity to translations and rotations make the method inapplicable unless the parameters are filtered or very specific. Furthermore, when objects overlap or are only partially observed, their properties are generally inadequate for recognition.

Two other possibilities for automatic recognition are being considered. First, the curvature, derived from the tangents at the contour points, defines a local descriptor. The function is noise sensitive, but the noise can be reduced by iterative curvilinear filtering. The problem is to find a good estimate of the curvilinear abscissas.

Second, in the preprocessing a coding of the contour in terms of symbols representing structures of a higher order than straight lines, arcs, corners, can be obtained. A rapid approximation can be used to translate the contour point list into a succession of arcs and straight lines. The basic idea is to find the arc best approximating the maximum number of contour poihts.

Models must be used for recognition of partially observed objects. The model adopted respects the two-dimensional nature of the piece. It can be viewed as describing a prototype pattern of the object and as a generative or relational model describing how the

prototype can be constructed. In building a model, some primitives are intentionally chosen and their appearances recorded during a learning phase. Production rules describing the structure of the object are then generated.

The aim is to find a prototype that best matches the shape. The prototypes are unstructured according to a decision tree generated during the learning phase. During identification, the most pertinent primitive in the image is sought, and an evaluation of the matching is calculated. Using the value obtained with the the decision tree, a production rule is called. The object is considered recognized when the function passes a predefined confidence threshold.

Control of Robots for Assembly

The research at LAAS in this area is mainly concerned with control of the space and the efforts by a robot manipulator to assemble pieces.

The research focuses on the control of a robot that manipulates pieces on contact. One must take into account the forces caused by contact and their implication for the general behavior of the manipulator. The task is fitting and inserting.

The parallel development of research in an experimental field integrating the results in visual perception and robot operator interaction has shown:

- The impact of real constraints on the orientation of research.
- The need to consider the manipulator in its global context and to develop functional models to satisfy many objectives.
- The need to introduce methods to calibrate inspection so the robot's work and use are easier.
- The need for--and possibility of--integrating a nonspecialized assembly system at the experimental level so that acquired knowledge can be condensed.

There has also been research on the control of the large movements of the manipulator, and work has been done on the geometric, cinematic, and dynamic modelling of a mechanically controlled structure without loops. The research was conducted using a formal description of a tree structure allowing the automatic writing of usable literal models. The approach permits, in parallel, the determination of the singularities of a manipulator, such as loss of degree of freedom by alignment of the axis of rotation.

Some laws of control of cinematic type have been determined; a 6 × 6 Jacobian matrix and its inverse are used. One strategy permits reducing the calculation of the inverse of the matrix by judicious use of the structure's properties.

LAAS has made one contribution to the theory of dynamic control; it appeared to be desirable to prepare the control unit to handle better the high speed evolutions, bringing into play inertial phenomena. No implementation could be realized because the sampling period was too long compared to the expected speed.

Paralleling this work, means of describing and smoothing a trajectory have been studied to avoid discontinuities of speed and to reach temporal trajectories in near-optimal time.

Work is beginning on the control of a manipulator TH8. The technical realities, such as friction and the environment, have led to some specific methods of subjection. The methods permit not only the use of manipulators for assembly, but also the exploitation of dynamic control for increasing the performance of trajectories.

Comments

The work at LAAS appears to be of high technical quality; the members of the technical staff with whom the author spoke were well informed and enthusiastic about their research.

J.F. Blackburn

ELECTRONICS

EUROPEAN MMIC LEADERS CONVENE

European leaders in the field of gallium arsenide (GaAs) integrated circuits (ICs) recently convened in London under the sponsorship of the Institute of Physics.

The purpose of the meeting was twofold. First, the latest advances in GaAs ICs were described and discussed. Second, and more informally, the scientists discussed the possibility of conducting an annual all-European GaAs IC Symposium similar to the one in the US. Consideration of such an undertaking reflects the rapid growth of the field. Although a decision about such a symposium has not yet been made, considerable enthusiasm was expressed. (Dr. I.R. Sanders of Plessey may organize the meeting.)

CISE Research

A novel and far-reaching development in monolithic microwave (MM) IC design was presented by Dr. Bastida of the Center for Information, Studies, and Experiences (CISE) in Milan, Italy. Although CISE is not widely known in the US, they are "coming on strong" in MMIC development (ESN 36-9:210-211 [1982]). The Bastida paper described a clever approach to overcome the notorious low yield problem associated with MMIC production. The fascinating aspect of his technique is that it does not impair MMIC performance. While modern precision lithography techniques have led to high yield fabrication of individual field effect transistors (FETs) characterized by submicrometer control gates, MMIC production with submicrometer features is now a low yield process.

In a typical low noise microwave amplifier circuit, only the first FET in the cascade requires submicrometer lithographic features, yet this integral and critical part affects the yield of the entire amplifier. To overcome the problem, Dr. Bastida designs the entire MMIC using high yield 1.0-micrometer lithography but leaves a semi-insulating region on the MMIC where the front-end submicrometer FET would normally be placed. On a separate wafer he fabricates the mirror image of this omitted submicrometer FET. A high yield is achieved on both wafers. The individual submicrometer FETs are "diced" and "flip-chip" mounted into place on the MMIC circuit. Thus, with a high production yield, MMIC technology's size, performance and cost become attractive.

Conventional hybrid microwave IC construction is characterized by 50-Ω interstage impedance nodes. While this greatly facilitates IC testing and enables the tweaking of individual stages, the 50-Ω-interstage impedance is artificial and generally degrades overall performance--especially bandwidth. Because tweaking is not possible with MMIC technology, it is advantageous to attempt to optimize interstage impedance matching circuits. Unfortunately, computer aided design (CAD) of MMIC circuits is in its infancy; the result is inferior interstage matching. Because MMIC lithography masks can cost more than $5,000 and can take more than 6 weeks to make, quality is sometimes compromised and undesirable results accepted.

The Bastida flip-chip approach overcomes these problems. By leaving the interstage impedance matching network region void on the MMIC wafer, mirror image interstage impedance matching networks of various types (fabricated on another GaAs wafer) can be flip-chip tested on the master MMIC circuit. Because the flip-chip mounted networks are held in place only by pressure, nondestructive testing is possible.

Other novel features described by Bastida included the use of slow wave interstage networks featuring "Qs" of 120 and stable MMIC oscillators. The latter were cleverly designed to accept a miniature dielectric resonator disc placed tangentially to each of two microstrip transmission lines connected to the FET gate and drain contacts.

DBS Work

The direct broadcast satellite (DBS)-to-home TV receiver market has been analyzed by Philips L.E.P. of France. They estimate the annual market to be 5 to 10 million in the US, 1 million in Canada, and 3 to 5 million in the UK and Europe. Accordingly, they have continued their vigorous pursuit to be the first commercial supplier outside Japan. Their current receiver development consists of a low noise amplifier (LNA), image rejection filter, mixer, local oscillator (LO), and intermediate frequency (i.f.) amplifier. The original LNA specifications called for a single stage amplifier exhibiting a 3.6-dB noise figure (NF) and 7.3 dB of gain. The revised specifications call for a two-stage LNA, NF<4 dB, overall gain of 30 dB, 11.7- to 12.5-GHz operation, 10.75-GHz LO, and an i.f. output in the 0.95- to 1.75-GHz spectrum.

Design and construction approaches for the DBS receiver include the use of interdigitated capacitors featuring 10-μm fingers and 5-μm gaps to achieve 5 pF/mm². Metallization thickness is three or four skin depths or 2.3 μm. The mixer is a dual gate FET whose NF is 6 to 7 dB. The LO uses a dielectric disc resonator in the gate lead of the FET and provides 13-dBm power output. Unfortunately its frequency drift is 5 MHz (approximately 1 TV band) over the operating temperature range and will most certainly require the addition of an automatic frequency control circuit. The image rejection filter uses an active bandpass filter concept and is believed to be the first such active filter developed for MMIC use. The i.f. amplifier is direct coupled, uses active impedance matching techniques, and incorporates negative feedback.

Other DBS receiver work is ongoing at Thompson-CSF and Siemans. In the US, only Rockwell International is known to have fabricated an X-band superhet receiver-on-a-chip.

Input Power Distribution

The latest fad in MMIC technology is that of the extremely broadband distributed amplifier. For 2 years this work was exclusive to four US organizations, but General Electric Company (GEC) UK (no relation to its US namesake) has now released details on two such efforts. One is a 0- to 1-GHz device exhibiting 9.2-dB gain. A novel design feature of the device is that the input impedance of each FET along the distributed input line is deliberately mismatched to the line. In so doing, the input signal power can be more uniformly distributed among the FETs in the amplifier. Also under design but not yet completed are 0- to 10-GHz and ultra-wide-band 0- to 13-GHz units. These are expected to be used for electronic countermeasures, electronic support measures, and low-probability-of-intercept (LPI) radar.

Size Reduction

Although MMIC design represents a size reduction to nearly one-hundredth of previous hybrid MIC technology, the Thompson-CSF group seeks another hundredfold reduction. As a first step toward this objective they have built an X-band amplifier that occupies only 0.17 mm^2 of GaAs and exhibits 6 dB of gain. It was direct coupled to eliminate area-consuming interdigitated capacitors. The next step will be to incorporate high dielectric materials such as Ta_2O_5.

Phase Shifting

Monolithic phase shifter work is beginning at Plessey. The approach is similar to that used by TRW in the US. The devices represent a fundamentally different approach to phase shift and can be used as phase rotators and modulators.

Design

An interesting approach to monolithic millimeter wave (mmλ) integrated circuit design was presented by J. Mun of the ITT Standard Telecommunications Laboratories. The approach is based on the much lower propagation losses encountered in rectangular waveguides than in microstrip transmission lines. Using rectangular waveguides as both input and output media, Mun first investigated E field coupling between the two waveguides via a microstrip resonant coupler photolithographically fabricated on semi-insulating GaAs (Figure 1). Once the principle was demonstrated, the resonant coupler was replaced with active GaAs amplifier circuits whose input and output circuits were E field probes extending into their respective waveguides.

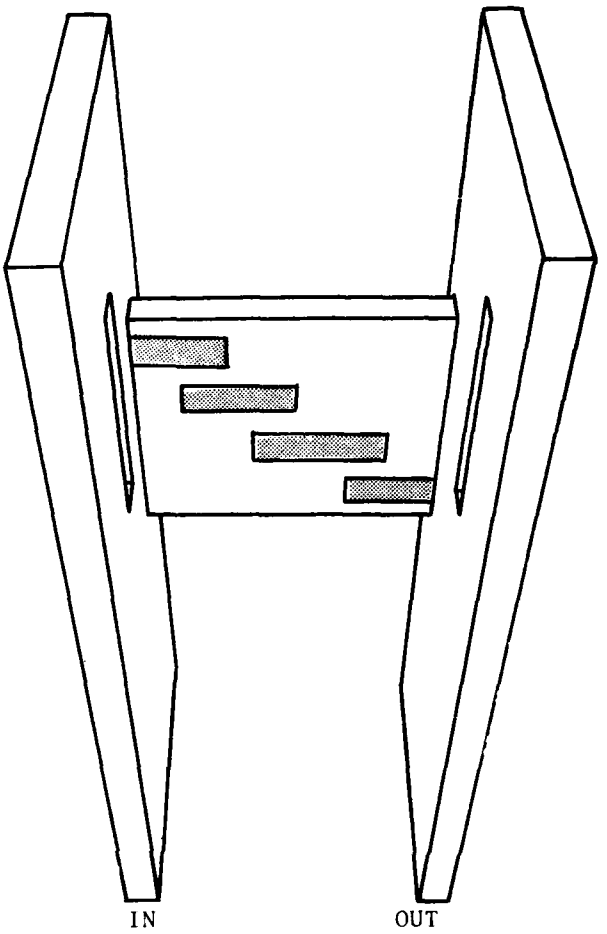

Figure 1. Microstrip resonant coupler.

Other papers were presented at the symposium, but they generally represented evolutionary advances of well-known techniques. The meeting illustrated both the breadth and depth of European MMIC technology. Whereas US MMIC technology is predominantly supported by the Department of Defense, the European effort has a much larger commercial orientation.

M.N. Yoder

THE 1982 FRENCH MEETING ON FERROELECTRICITY

On 20 September 1982, the Réunion Francaise de Ferroélectricité was held at the Faculté des Sciences in LeMans,

France. The primary purpose of this meeting, which is held biannually, is to exchange ideas among French scientists working with ferroelectric materials.

This year the meeting was attended by over 100 scientists from 21 laboratories. Invited lectures were given by J.C. Toledano (Centre National d'Etudes des Télécommunications, Bagneux), L.L. Boyer (Naval Research Laboratory, Washington, DC), and F. Micheron (Laboratoire Central de Recherches, Orsay). Each lecture was followed by well-attended poster sessions.

Critical Phenomena

In the past 10 years there has been a large amount of research in the area of critical phenomena. The research has been encouraged by theoretical developments originating with the famous work of Kenneth Wilson (a recent Nobel prize winner) in what has come to be known as renormalization group theory of phase transitions. The important result of the theory is that certain properties of phase transitions (critical exponents) are universal functions of the number of components of the order parameter and the dimensionality of the system. In other words, the critical exponents are independent of the specific interactions of the system--except, of course, to the extent that they determine the order parameter and dimensionality.

Toledano's lecture dealt with the subject of critical phenomena as it relates to displacive transitions in ferroelectric materials. An extensive compilation of critical exponents was presented, revealing that a number of large discrepancies were due to crystal defects. Recent theories for including the effect of defects on critical behavior were cited.

Universal Properties

By way of contrast, Boyer described a theory for calculating nonuniversal properties of displacive transitions; properties which orginate from the detailed interatomic forces involved, such as the driving mechanisms for the transition and the transition temperature. The theory is based on an ab initio derivation of the interatomic forces (Gordon-Kim method) and therefore can make genuine predictions. Calculations for the fluoperovskite, $RbCaF_3$, were found to be consistent with the observed displacive transition in the material. Significantly, the same theory predicts the absence of any displacive transition in $CsCaF_3$, in agreement with experiment.

Applications of Ferroelectric Materials

F. Micheron gave a report on the current status of the applications of ferroelectric materials. He pointed out that while applications are mainly in piezoelectric and photoelectrooptic (modulation of optical properties by an optical frequency signal) areas, there is still a need for further advanced studies in areas such as polycrystalline dielectric and pyroelectric materials. In piezoelectric materials there has been progress in exploiting the heterogeneity of composite materials to enhance desirable properties. Controllable parameters, such as respective concentrations of phases or dimensions and arrangement of inclusions, can be used to decouple, in part, properties that are not independent in the single phase (e.g., polarization, permittivity, Young's modulus, Poisson's ratio), and to optimize certain piezoelectric coefficients. The largest photoelectrooptic effects have been found in $BaTiO_3$ followed by $K(Ta,Nb)O_3$.

Poster Sessions

It was clear from the posters and the size of the meeting that the French continue to be strong in the field of ferroelectric materials. A wide variety of materials are being studied by many different experimental techniques; there appears to be a strong and increasing effort in theory as well. A great deal of work is being devoted to halides (especially fluorides), which form in the perovskite structure. The group at LeMans has developed an excellent fluoride crystal growth facility from which some of the first good single crystals of such materials were grown. Research in the area may lead to a better understanding of displacive transitions in general because the interactions in the materials are relatively well understood, and their structure is simple enough to permit meaningful calculations.

Those who would like further details of this meeting should address correspondence to Dr. M. Rousseau, Laboratoire de Physique de l'Etat Condensé, Faculté des Sciences, Route de Laval, 72017 LeMans Cedex, France. Proceedings of the conference will not be published.

ONR Washington, DC

MATERIAL SCIENCES

HIGH TEMPERATURE ALLOYS FOR GAS TURBINES 1982

A conference on high temperature alloys for gas turbines was held from 4 through 6 October 1982 at Palais des Congrès, Liège, Belgium. The conference was sponsored by "COST-50," a European collaboration of science and technology on materials for gas turbines, initiated in 1971 and supported since then by the Commission of European Communities (CEC). A conference was held at Liège in 1978 covering results from 1974 through 1977, designated Round 1 of the COST-50 program. The proceedings of the Round 1 meeting were published by Applied Science Publishers Ltd.

The current meeting covered Round 2 (1978 to 1982) and was devoted to corrosion and coatings; fatigue, creep, and structural stability; and processing. There were 286 attendees representing 17 countries. The US was fifth highest in attendance with 22 persons, while Germany had 61, Belgium 47, France 43, and the UK 39. Only 51 represented universities, indicating the industrial emphasis in this subject of advanced technology. Papers were presented in English, French, or German with simultaneous translation.

Prof. H. Fischmeister, Max Planck Institut für Metallforschung, Stuttgart, is chairman of the COST-50 Management Committee. He pointed out that gas turbines represented a business of approximately $1 billion for the CEC, which includes Austria, Belgium, the Federal Republic of Germany, France, Italy, Netherlands, Sweden, Switzerland, and the UK.

J.P. Contzen, from France, CEC Director of Science and Technology Policy, listed the following major goals of the European Economic Community (EEC) Research and Development Policy: promoting agricultural and industrial competitiveness; improving the management of raw materials and energy resources; reinforcing development aid; improving living and working conditions; and improving the efficacy of the EEC's science and technology potential (see I.M. Bernstein, "Materials Problems at the Joint Research Centre," ESN 32-11:375-377 [1978]). Two main activities of EEC energy resource management are developing nuclear power and thermonuclear fusion.

The papers in the technical program were preprinted by D. Reidel Publishing Company, Boston, in a 1,079 page book, High Temperature Alloys for Gas Turbines 1982, editors R. Brunetaud, Société Nationale d'Etude et de Construction de Moteurs d'Aviation (SNECMA), France; D. Coutsouradis, Centre de Recherches Metallurgiques, Belgium; T.B. Gibbons, National Physical Laboratory (NPL), UK; Y. Lindblom, Förenade Fabriksverken (FFV), Sweden; D.B. Meadowcroft, Central Electricity Generating Board, UK; and R. Stickler, Univ. Wien, Austria. Fifty-four papers are included in the book, headed by the keynote paper "Superalloy Technology--Today and Tomorrow," delivered by F.L. VerSnyder, United Technologies Research Center, East Hartford, CT 06108. The conference and proceedings were dedicated to the memory of Prof. Louis Habraken for his outstanding contributions to the materials science of gas turbine materials and COST-50.

Superalloys

VerSnyder concentrated on three aspects of nickel-based superalloy processing developments: superalloy powder metallurgy technology (SPMT), investment casting technology (ICT), and rapid solidification technology (RST). Engineering advancements in high temperature, high strength-low weight materials are especially important now because about 40% of aircraft costs are for fuel.

A main stimulus for the SPMT activity was simply to solve the forging problems generated because superalloys are so exceptionally strong. Methods of argon gas atomization, spraying from a rotating electrode, and the pressure-driven vacuum expansion of gas-saturated molten metal are used to produce powders. Although oxidation problems are caused by the compaction of powders at high temperatures, the important problem of macro-segregation in castings is avoided. A "gatorizing" process is used to superplastically extrude the canned hot compacted powder product. Sometimes, hot isostatic pressing of parts to near-final shape can be done to reduce the content of ceramic inclusions in the material.

Superalloy ICT is centered on directional solidification for either columnar grains or single crystal turbine blades, which are now functioning in commercial high pressure turbines after established use in military engines. Vacuum casting is done under the following conditions: the crystal growth rate is determined by unidirectional heat flow through a chilled surface, and the thermal gradient is controlled by induction heating. A grain selection process is used to terminate multiple grains at premold

constrictions. Future blades will involve directionally solidified eutectic alloys. An example described was an Fe-20Cr-10Mn-3.2C alloy, which gives γ Fe plus $(Cr,Mn)_7C_3$. A movie was shown of an automated crystal production line with robotic handling of the molds and crystal products in their high temperature environments.

Solidification of powder droplets, melt spinning of ribbons, and the in situ melting of thin surface layers are included in RST. Stable micro-crystalline structures are of concern for high temperature gas turbine applications. A centrifugal atomization process produces 10- to 100-micron-size particles from a disk spinning at 24,000 rpm. A cooling rate of about 1,000,000°C/s is achieved for the particles by helium gas quenching. The new RST achievements allow: (1) the possibility of high temperature superplastic forming at low strength levels due to the deformation properties of such ultrafine microstructures, and (2) improved strength for the same material at the lower temperatures of engineering application. (See R.W. Armstrong, Ultrafine-Grain Metals [Syracuse University Press, N.Y., 1970], p 1.)

Focused laser (or electron) beam heating provides an intense energy source for rapid melting of local surface layers, which then experience extremely high cooling rates due to self-quenching. A laser glazing process has been developed with beam power densities in the range of 10^4 to 10^7 W/cm². Another product of research on laser processing of materials is called "layer glazing" for directed energy in situ processing of metal deposition from powder or wire feed stock. Repetitive layers of bi-metallic disks have been produced from the buildup of individual layer thicknesses of about 125 μm. Fully dense material is produced by remelting the top layer of the previously deposited material when the next layer is added; so the successive layers are properly fused together on the micro scale. Chemical homogenization is no problem. Provision is made for subsequent thermal treatment to recrystallize the material when exceptional thermal strains are produced.

Corrosion and Coatings

In the conference book there are nine articles on corrosion and coatings; the six described below are the review papers. R. Pichoir, Office National d'Etudes et de Recherches Aérospatiales (ONERA), France, gave a paper "Recent Approaches to the Development of Corrosion Resistant Coatings," co-authored with C. Duret, ONERA; A. Davin, Centre de Recherches Métallurgiques, Belgium; and G. Marijnissen, ELBAR b.v. Industrieterrein Spikweien, Netherlands. Aluminide or silicide intermetallic coatings or complex alloys involving iron, nickel, cobalt, chromium, aluminum and yttrium (by chemical vapor deposition), are used to counteract acid fluxing sulphidation, hot corrosion by molten sodium sulphate, and high temperature oxidation. Overlay coatings of complex alloys are applied mostly by plasma vapor deposition methods, including the laser melting methods described for RST. Low thermal conductivity materials, such as zirconium oxide, are applied with intermediate compliant bonding layers of the complex alloys to provide thermal barrier coatings. In all cases, rather sophisticated metallographic procedures have been developed to assess the quality of the coatings and their service properties. Five additional papers were presented on the topic; they dealt with the corrosion properties of various coatings, the fuel deposition and blade fouling of gas turbines, and combined high temperature erosion and corrosion properties of superalloys.

Fatigue, Creep, and Structural Stability

Ten of the 31 papers on this topic were reviews. In the opening paper, P. Senechal, SNECMA, described results of a finite element analysis of the stress state generated at the disk slot and blade root of a turbine system. The analysis was compared with photoelastic experiments on an epoxy resin scale model. Life predictions based on fatigue and creep behavior were made in this paper and one by G.B. Thomas, NPL, UK; J. Bressers, CEC Joint Research Centre, Netherlands; and D. Raynor, Central Electricity Research Laboratories, UK.

The fatigue and creep behavior of alloys IN 738LC and IN 939 were considered in detail in a number of papers--for example, "IN 939 Metallurgy, Properties and Performance," by T.B. Gibbons, NPL, and R. Stickler, Univ. Wien, Austria. The paper emphasized new data obtained through COST-50 sponsorship. The mechanical properties of IN 939 compare favorably with those of IN 738LC; otherwise, IN 939 has superior in-service corrosion resistance. V. Lupinc, ITM-CNR, Italy, covered "Creep Strengthening Mechanisms" for the superalloys. Y. Lindblom, FFV, Sweden, and G. Engberg, Swedish Institute for Metals Research, Stockholm, continued with "Creep Damage and Fracture." An

important paper was by E. Lang, CEC Joint Research Centre, co-authored with A. Strang, GEC Turbine Generators, Ltd, UK, on "Effects of Coating on the Mechanical Properties of Superalloys." The effect of coating on creep life was characterized by Larson-Miller plots. The ductile-brittle transition temperature for various coating systems was described. H.W. Gruenling, Brown Boveri and Cie (BBC) AG, Germany; K.H. Keienburg, Kraftwerk Union AG, Germany; and, K.K. Schweitzer, Motoren-und Turbinen-Union (MTU) GmbH, Germany, presented "The Interaction of High Temperature Corrosion and Mechanical Properties of Alloys," in which gas turbines for land-based, marine, and aerospace applications were considered.

Processing

In his keynote paper, VerSnyder emphasized the importance of new and improved processing methods for the continued growth and development of superalloy use in the turbine industry. Thirteen papers were presented on this subject; six were reviews covering melting, casting, powder metallurgy, joining, and blade repair. In "VADER--A New Melting and Casting Technology," a paper co-authored with G.E. Maurer and C.B. Adasczik of Special Metals, New Hartford, CT, W.J. Boesch described the development of a method of vacuum arc-dual electrode remelting (VADER).

Other papers were concerned with forging of disks (J.E. Coyne and W.H. Couts, Jr., Wyman Gordon Co., Worcester, MA), powder metallurgy processing (J.H. Davidson, Imphy S.A., France, and C. Aubin, Ecole des Mines de Paris), directional recrystallization of oxide dispersion strengthened superalloys (G.A.J. Hack, Wiggin Alloys, Hereford, UK), and precision casting (papers by J.M. Drapier, Fabrique Nationale, Herstal, Belgium, and R.H. Lyon and W. Barice, Precision Castparts, Portland, OR).

H. Boehmer, DFVLR, Germany, presented a paper not included in the conference proceedings. "The German Ceramics Gas Turbine Component Program: Goal, Results and Perspectives" represented the first ceramics effort in COST-50. The advantages of the gas turbine include: the elimination of fuel additives, reduced vibration, energy savings due to higher operating temperatures, a low weight engine, and inexpensive fuel, such as 70% crude oil, methanol, or even coal dust. Silicon nitride or silicon carbide is required for an operating temperature of 1350°C. The German approach has been to make ceramic turbine components (at MTU), whereas the US has a comprehensive program for developing a complete ceramic turbine. Single block rotors have been made of silicon nitride. Boehmer said that the prospects for the development of ceramic components on a small scale were encouraging.

P. Adam described his work with H. Wilhelm at MTU on the "Welding of PM-Superalloys." Electron beam welding was studied because under any circumstances the welding of precipitation strengthened alloys is extremely difficult. Thermal stresses leading to micro-cracking are a major problem. Microhardness test results were used to assess the strength results in the fusion zone and in the adjacent heat affected zone. From separate tests of properly welded materials, the yield stress and tensile strength might be decreased about 10%, while the creep properties were unchanged or even slightly improved. The fatigue life might be reduced as much as 20%. Adam summarized by saying that powder metallurgy nickel-base superalloys are difficult to weld by any means and, of the various methods, diffusion welding was the least attractive.

A final paper on processing was given by M.H. Haafkens, Elbar b.v. Lomm, Netherlands, on "Blade Repair and Recovery." About 5 years ago it was decided that reclaiming rotating blades and buckets of difficult-to-weld superalloy materials was an important consideration. The paper dealt mainly with several topics: restoration of material properties by heat treatment and joining in a containerless hot isostatic compaction environment, welding procedures, and repair brazing. The consideration of coatings was important, and research in COST-50 had produced three new coatings of TiSi, CrAl, and CoCrAlY alloys. Computer-aided analysis also is done for engineering calculations, robot welding, robot plasma spraying of coatings, and heat treatment considerations.

Poster and Industrial Presentations

Forty-seven poster presentations were divided among the three topics: 10 on corrosion and coatings; 25 on deformation and structural stability; and 12 on processing. J.F.G. Condé, with G.C. Booth and A.F. Taylor (Admiralty Marine Technology Establishment, Poole, UK), and C.G. McCreath (Univ. of Sheffield) described results of hot corrosion in marine gas turbines. W. Hoffelner, BBC, showed fatigue crack growth data obtained at conventional and ultrasonic frequencies to investigate the utility of obtaining results faster

ultrasonically (see R.W. Armstrong, ESN 36-10:250-253 [1982]).

K.M. Delargy and G.D.W. Smith (Oxford Univ.) presented results on the "Phase Composition and Phase Stability of Alloy IN 939." Several microscopy techniques were used, including the method of atom probe time of flight mass spectrometry (ESN 36-10:272 [1982]). An impressive poster display was entitled "Alloy Design for Nickel-Base Superalloys," by H. Harada, M. Yamazaki, Y. Koizumi, N. Sakuma, and N. Kamiya, National Research Institute for Metals, Tokyo, and H. Kamiya, Daido Steel, Nagoya, Japan. The poster showed a computer analysis method for designing alloys by incorporating structural and properties data. Among the processing posters was one on "Investigation of the Surface Grain Refinement for Superalloy Castings," by J. Fang, Beijing Institute of Aeronautics and Astronautics, and B. Yu, Dung an Machinery Factory, People's Republic of China.

The industrial display of materials and turbine parts at the conference was about the same size as the total display of posters. US manufacturers were Cannon-Muskegon Corp., single crystal alloy materials by vacuum remelting for turbine components; Howmet Turbine Components Corp., titanium castings; and SermeTel, Inc., turbine engine components--including coating systems. Testing equipment was advertised by Instron, Ltd., and by W.H. Mayes and Son, Berkshire, England. European manufacturers of materials and turbine parts included Vereinigte Edelstahlwerke Aktiengesellschaft, Austria; Fabrique Nationale Herstal S.A., Belgium; Imphy (Creusot-Loire), France; Elbar b.v. Industrieterrein Spikweien, Netherlands; Brown Boveri and Cie, and Sulzer, both from Switzerland; and Wiggins Alloys, Ltd., UK.

R.W. Armstrong

OCEAN SCIENCES

NEW TECHNIQUES FOR ANALYZING ORGANIC MATERIALS

The Biological and Chemical Oceanography Branch of the Naval Ocean Research and Development Activity (NORDA, Bay St. Louis, MS) has been exploring new directions for analyzing organic materials in the marine environment. The objective is to develop a technique that provides considerable information while requiring small samples, few personnel, and simple laboratory preparation. The technique must also take into consideration that most of the organic materials in the marine environment are polar and not readily volatile.

The approach that has been developed is based on pyrolysis-mass spectrometry (PY-MS). Sample preparation and analysis take about 15 minutes. All components are linked, thereby decreasing the chance for sample contamination (Journal of Analytical and Applied Pyrolysis, Vol 4, No. 47 [1982]). However, there are some limitations. High accuracy mass measurements of the pyrolyzates cannot be obtained with the instrument at NORDA, making identification highly tentative. The pyrolyzates can be identified more accurately with two other approaches: high resolution MS or the insertion of a gas chromatographic step for pyrolysis-gas chromatography spectrometry (PY-GC-MS).

An additional difficulty is the development of a mathematical approach to interpret correctly the huge amount of data made available by PY-MS. Also of interest are other means for volatizing organic materials--e.g., by lasers, field desorption, or field ionization. NORDA staff recently visited European laboratories having the most experience in PY-MS: the Univ. of Bonn, the Technical Univ. of Delft, and the Fundamental Investigation on Matter (FOM) Inst. for Atom and Molecular Physics in Amsterdam.

Univ. of Bonn

Prof. Hans-Rolf Schulten and his group were at the Institute for Physical Chemistry of the Univ. of Bonn. (In January 1983 he moved his group, and their instruments, to the Department of Trace Analysis of the Fachhochschule Fresenins in Wiesbaden.)

Schulten has done pioneering work in the volatilization of organic materials with ion and field desorption mass spectrometry. He has been especially active in the development of the latter technique and enjoys a worldwide reputation. He has published extensively, including an excellent 186-page review dealing with field ionization and field desorption (International Journal of Mass Spectrometry and Ion Physics, Vol 32, No. 97 [1979]).

His laboratory has both an MAT 731 mass spectrometer capable of volatilizing a sample with field-desorption, Curie point pyrolysis, or laser beam, and a CEC 110B high resolution double focusing mass spectrometer with field-desorption or Curie point pyrolysis

capability. The CEC spectrometer uses a photoplate detector, which allows considerably more accurate mass assignments but is time consuming to use. Schulten has done a large amount of environmental work, often with Delft and Amsterdam, but much of his research now deals with physiological fluids, especially in relation to multiple sclerosis. Field-desorption is especially useful for this because it gives information about the presence of both organic and inorganic materials.

Technical Univ. of Delft

The Organic Geochemistry Unit of the Technical Univ. of Delft (Technische Hogeschool Delft) is under the leadership of Prof. P.A. Schenk. One of the group leaders is Dr. Jan W. De Leeuw, who has had considerable experience analyzing the organic material in sediments and particles with PY-GC and PY-GC-MS. PY-MS work is usually done in cooperation with the FOM Institute in Amsterdam.

Research is now under way in organic carbon rhythms in shales (Dr. Ger van Graas), carbohydrate distributions in Walvis Bay sediments (Dr. Jacob Klok), and humic acid identification (Dr. C. Saiz-Jimenez, a guest scientist from Seville, Spain). Besides the usual gas chromatographs (GCs), the chief instruments available for this work are a Model 419 Packard-Becker GC with a Fisher Curie point pyrolyzer for PY-GC, and a 44S MAT quadrupole with a Varian 3700 and a Curie point pyrolyzer for PY-GC-MS.

AMOLF

AMOLF is an institute of the FOM section of the ZWO (the Dutch equivalent of the National Science Foundation in the US). AMOLF is in Amsterdam and is probably the most hardware-oriented and experienced of all the institutes visited. It has very large facilities, complete with machining and instrument design capabilities.

Dr. Johan Haverkamp, Biomolecular Physics Branch, has been interested primarily in PY-MS work and the mathematical interpretation of the resulting data. He has published many scientific papers and has co-authored a book dealing with PY-MS. The chief analytical device used in his research is a Riber mass spectrometer with a Curie point pyrolysis unit. It has the unique feature of being able to process samples automatically. Laser desorption can also be used in a different instrument, but Dr. Haverkamp finds that the reproducibility is inadequate. For detailed elucidation of the structure of the pyrolyzates, a PY-GS-MS system is also available.

Sample Analysis

Environmental samples (sediment and water) were analyzed at NORDA and the three European institutes. The goal was to compare the various methods and the interpretation of the resulting data.

NORDA's approach is PY-MS with chemical ionization. It is rapid and has good reproducibility but relatively poor mass resolution for identifying pyrolyzates. The Univ. of Bonn's approach, based on MS with pyrolysis or field desorption, has good resolution but is slow. Furthermore, since the approach is for chemical identification, reproducibility plays a less important role.

At the Univ. of Delft, PY-GC and PY-GC-MS are used; both approaches are slow and have poor mass resolution. However, a great deal of additional information is potentially available because the pyrolyzates are separated by the GC component. This allows their mass spectra to be analyzed individually. The approach used at AMOLF resembles NORDA's most closely. However, there are some major differences. The pyrolysis techniques are different, and FOM uses electron impact rather than chemical ionization.

There should be considerably more information about the most valuable approach for analyzing organic matter in the environment when all the data have been collated in the next few months.

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OPERATIONS RESEARCH

A SYSTEMS APPROACH TO DEFENSE ANALYSIS

Computer simulations or mathematical abstractions can be used to model battles and support defense planning. Prof. R. Huber, Department of Computer Science, Federal Armed Forces Univ., Munich (FRG), is conducting research on the theory and modeling of military conflict and combat processes. He is interested in making quantitative assessments of force balance conditions, defense concepts, tactics and doctrine, with special concern for the roles of command, control, and communications (C^3).

Huber has long advocated use of what he calls a "Compound Gaming Approach" for analyzing force balance and developing stable defense concepts. During a recent visit, Huber described his approach, particularly the roles of "quick game" models at lower levels of force interactions, such as battalion versus regiment engagements.

Why Use Simulation?

Huber presents a forceful argument in support of using simulation experiments to assess the relative strengths of forces. In the past decade, there has been a tremendous accumulation of military hardware by the Soviet Union. Simultaneously, economic and political situations facing the West have made it difficult to match the Soviets' global threat. This means that now, more than ever before, all forces of the Atlantic Alliance must be well managed.

Traditionally, there has been much provincialism--by nations and service branches--in planning the use of their forces. Huber argues that, except for some token parts, NATO's defense system is a true system in name only. Rather than being the result of a systematic overall design, it basically comes about in piecemeal fashion from its essentially independently designed national subsystems. Also, in typical piecemeal fashion, most of today's national defense planning concerns only relatively low system levels and technical issues. Aggregating low level systems, even those which are cost effective on a per-unit basis, does not necessarily result in cost effective systems on an overall basis. This is so, Huber points out, because "additive" processes cannot be used to transform inputs, such as weapon systems and soldiers, into outputs, such as combat effectiveness. Rather, the processes exhibit structure such as diminishing returns and interactions that are exponential and multiplicative.

The piecemeal approaches to defense planning need to be replaced by a true systems approach in which defense is viewed on a global scale as one joint effort. Implementing a joint systems approach to defense planning will require rational debates among members of the alliance so that differences can be reconciled long before the critical stages of decision making are reached.

A basic prerequisite for rational debate is the availability of information that can be used to explain the rationale for national or institutional preferences. Such information should allow reproducible assessments of trade-offs among preferences of the possible options. Such information might come from analyses of empirical evidence or from experiments. Huber argues that the empirical data available from historical war records and personal combat experience have proved to be inconclusive in most cases. He thus concludes that experiments with models of force interactions provide the only viable sources of the required information. Because of time and cost constraints, most of the models will necessarily be mathematical abstractions or computer simulations; a small fraction of the modeling effort involves field experimentation.

Criticism of Models

Most of the criticisms of experiments with models to support defense planning concern the fact that, in many cases, the modeling and subsequent analyses tacitly accept certain philosophies, concepts, and principles as given, rather than making them subject to analysis. Huber provided an example demonstrating the impact of operational concepts on capabilities and structures of two opposing tactical air forces.

Huber has modeled tactical air operations in support of a land battle as a multistage game. At each time increment the adversaries in the game decide how to allocate their aircraft to the basic tactical air missions of offensive counter-air (OCA) and offensive air support (OAS). The allocation is made so that each side can support the land battle as effectively as possible.

This is a differential game in which the states d_t and a_t of the opposing air forces D (defender) and A (attacker) at time t are given by the state equations:

$$d_{t+1} = f(d_t, a_t, \delta_t, \alpha_t)$$

$$a_{t+1} = g(d_t, a_t, \delta_t, \alpha_t).$$

Here, δ_t and α_t denote the operational strategies of the respective adversaries, and f and g are functions representing factors such as weapons effectiveness, aircraft performance, and numbers of aircraft. The game theoretic value is given by

$$\min_{\delta_t} \max_{\alpha_t} U_t$$

where

$$U_t = I_D(\delta_t, \alpha_t)/I_A(\delta_t, \alpha_t)$$

is the utility function, with I_D and

I_A the offensive air support potential of defender and attacker, respectively. The terms defender (D) and attacker (A) do not imply that the respective antagonist is limited to defensive or offensive operations. They indicate only that the attacker initiates the hostilities (i.e., gets the first move in the game), to which the defender reacts.

Table 1 shows the results of several iterations of the game in terms of the relative OAS capabilities of D versus A.

Table 1

Relative OAS Capabilities of Defender Versus Attacker

	Attacker, A	
Defender, D	No OCA	Optimal OCA
No OCA	0.86	0.99
Optimal OCA	2.9	1.00

The values shown in the table are normalized such that the value is 1.00 for the "base" case where both sides pursue optimal OCA mission allocations. The other OAS capability values can be interpreted relative to that case. For example, whatever the actual OAS capability ratio may be in the base case, there is a reduction to 86% of that value if both sides allocated their aircraft to OAS only. The values show that the attacker is practically forced to open the campaign with an OCA operation; if A leaves the OCA to D, the OAS-potential ratio increases by 2.90, a significant factor.

Huber pointed out that the above example illustrates that, for given force structures on both sides, the balance may be significantly affected by each side's choice of operational concepts. The efficiency of a military operation is sensitive to the choices made by the enemy as well as to one's own choice of operational doctrine. This rather obvious fact is typical of what is sometimes overlooked in analyses of forces. A measurement of the relative strengths of forces must be made in a context that considers optimal use of forces by both sides, rather than with one side held static in an assumed scenario. Huber believes such assessments can be based on dynamic gaming models which "act out" combat. Gaming models can provide information relevant to assessing trade-offs among resources, force structure, and doctrine in a context that accounts for a potential opponent's reactions.

Hierarchical Gaming

In order to make high (theater") level assessments, Huber believes it is necessary to combine results of many games representing various lower levels of the system. He refers to this as hierarchical gaming. At each level, analyses give information on the adequacy and feasibility of objectives and scenarios of the next higher level. Similarly, the hierarchical approach also provides insights about the validity of the gaming models used. For example, a high level model, which is usually of low resolution (and high abstraction), cannot be validated directly using, say, field experiments. But if it is part of a hierarchy of "overlapping" models, it can be at least partially verified because the component at the lowest level, having high resolution, should be reproducible by physical experiments.

Hierarchical games are not yet routinely used for force balance assessments. On the one hand, military decision makers prefer high resolution games which, at the higher levels of the hierarchy, become very resource consuming. On the other hand, force planning problems involve large numbers of combinations of structures, technologies, operational concepts, tactics, and doctrines, so the models must run quickly.

In the past, a compromise between degree of resolution and response time has been attempted by considering some of the variables, such as tactics, to be "given." But we commented above that this does not generally lead to good overall solutions to force planning problems. Huber suggests using "quick games," such as the air force game described above, to supplement the higher resolution games at all levels of the gaming hierarchy. He proposes that the games be used to make a cursory check of the major effects of choices among the problem's variables. Quick games can help the analyst focus and structure problems better for subsequent investigation by higher resolution research games.

D.R. Barr

THAMES BARRIER BECOMES OPERATIONAL

The Thames barrier flood control gate system has recently become operational. The project, completed at a cost of about £ 500 million, has been

Figure 1. Artist's impression of the Thames barrier, looking downstream with gates closed.

under construction for about 10 years. The barrier itself consists of a string of four main and several lesser gates across the 520-m width of the River Thames near Greenwich (Figure 1).

The main gates, each spanning an opening about 60-m wide, are massive (3,300-ton) hollow "quarter cylinders" which can be rotated from a horizontal position at the bottom of the river into 20-m-tall gates. When the gates are in their usual lowered position, ocean-going ships can move through the barrier. (The River Thames remains a busy commercial waterway despite the closure of some of the up-river docks and placement of bridges along the river.)

When a dangerously high water surge threatens to cause flooding up-river, the gates can be rotated 90 degrees to form dams 20-m tall. The gate closure takes about 30 minutes, and it is desirable to provide ships at least a 2-hour closure warning. Thus, it is important to have at least 4-hour predictions of surge conditions; such predictions are accomplished with an extensive warning system network.

London has been at risk from tidal flooding throughout its history. The Anglo-Saxon Chronicle records a surge tide in the year 1089: "This year also, on the festival of St. Martin [in November] the sea flood sprung up to such a height and did so much harm as no man remembered that it ever did before." Samuel Pepys, in his Diary for December 1663, wrote, "There was last night the greatest tide that ever was remembered in England to have been in this river, all Whitehall having been drowned." In addition, many lives were lost in the flood of 1953.

There is strong evidence that flood levels have steadily gotten more severe with passing time. Figure 2 shows recorded flood levels, as well as "defense" levels at certain times at London Bridge. From the data in Figure 2, it appears that flood depths are increasing at a rate of about 2 ft per century. If there were no general increase in depth (for example if one imagines flood depths occur as largest order statistics in a sequence of independent, identical, normal annual

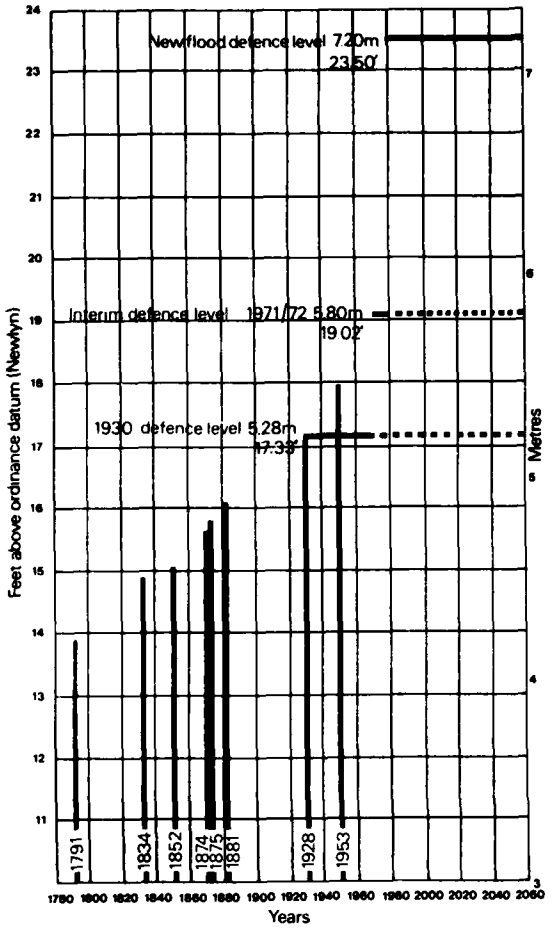

Figure 2. Increasing high tide levels and defense levels at London Bridge.

flood depths), the increase in flood depths in the second millennium of record-keeping should be at a very much smaller rate, possibly on the order of 0.1 ft per century.

There are several reasons for the increasing depths of surges on the Thames. Exceptionally high tides occur when the level of a high (spring) ocean tide is increased by a surge component. Surges result from low atmospheric pressure areas originating in the North Atlantic and driven southward along the east coast of Britain and into the channel and Thames estuary. The shallow water of the continental shelf and the "funneling" effect at the mouth of the Thames can amplify a 0.3-m atmospheric surge into a 3.5-m surge on the river itself. In addition to superimposition of storm surges and tidal effects, which presumably are fairly stationary (in a stochastic sense) over time, there are several possible interacting factors that are making the flood tides higher (relative to London Bridge, for example). It is thought that the southeast of England is sinking relative to mean sea level, possibly at a rate of about 0.3 m per century; there is a general increase in ocean depths due to melting of the polar ice caps; dredging operations in the Thames estuary to improve navigational channels have increased the speed of movement of tidal waves; and flood prevention measures downstream, such as increasing bank heights along the river, restrict the spread of incoming tides.

The Thames barrier will be manned continuously by a small team of operators. Significant work has been done to make the system reliable. For example, emergency stand-by generators can provide power, through an alternate distribution system, to raise and lower the barriers. There is a local control center on each pier (between gates of the barrier) to provide emergency backup to operation from the central control room on the south bank. The barrier closure must be carried out in a prescribed manner to prevent creating flood levels downstream that are significantly higher than would otherwise be experienced. Such downstream effects can be caused by a reflected wave, involving reflection of a surge moving upstream from a closed barrier.

Closure plans call for rotating the barrier cylinders through an angle greater than 90 degrees so that there is a 1-m gap between the bottom edge of the barrier cylinder and the concrete sill at the bottom of the river. Flow of water under the gate (before surge arrival) has the effect of lowering the river level just downstream of the barrier, which counteracts the wave reflection effect. In addition to preventing reflected waves once the decision to close the barrier has been made, barrier operators must limit both the number of unnecessary closures and shipping delays.

To meet the above responsibilities, adequate forecasts of river depths must be provided. This is done with a numerical model called the Thames Barrier Operations Model. The model provides accurate forecasts of river levels at 28 locations along the Thames; determines, during forecast periods of up to 36 hours, whether barrier closure is required; and, if so, gives the optimum time, mode, and duration of closure. The Surge Tide Forecast Model (STEM), which is part of the Thames Barrier Operations Model, provides river

depth forecasts. The STEM is a finite elements model based on the Southern Bight of the North Sea Model developed by Dr. D. Prandle of the Institute of Oceanographic Sciences, Bidston, UK. It has been implemented by Mr. A.L. Still of the Department of Public Health Engineering, Greater London Council (GLC). Data input to the model include:

1. Forecasts of wind speeds and directions and forecasts of atmospheric pressures over a 36-hour period (obtained from the Meterological Office, Bracknell, UK);
2. Surge residuals recorded at several sites along the British coast and reported by the UK's Storm Tide Warning Service; and
3. Water flow levels in the Thames, provided by ultrasonic water gauges. By comparing observed depths with forecast depths, it has been possible to improve the model so that its 36-hour forecasts are "useful," and its 8-hour forecasts are quite accurate.

The GLC, London's regional government body, has had the primary responsibility of managing flood control measures for London, including the barrier project.

D.E. Barr

PHYSICS

AN OPTICAL DIAGNOSTIC FOR HIGH CURRENT MEASUREMENTS

In 1845, Faraday discovered that glass and some other substances acquire the property of optical activity when placed in a strong magnetic field. The so-called Faraday effect refers to a rotation of the polarization plane when light traverses a substance along the magnetic lines of force. The direction of rotation is reversed if the field is reversed but is the same with respect to the observer whether the light is going or coming. Thus, a beam passing one way followed by a back reflection has its rotation doubled. This is not the case in materials that are naturally active without magnetic fields.

For magneto-active solids, the polarization rotation angle is determined from

$$\phi = V\int \underline{H}\cdot d\underline{l} \qquad (1)$$

where the integral is along the optical path, $\underline{H}$ is the magnetic intensity (usually measured in ampere-turns/meter), and V, the Verdet constant, is determined by the magnetic properties of the material. In diamagnetic materials, V is proportional to the dispersion $dn/d\lambda$ (refractive index n, radiation wavelength λ) and decreases with increasing wavelength. For fused silica at λ = 0.44 μm, V is 0.021 min/A and drops to 0.006 min/A at 0.83 μm (A. Papp and H. Harms, Applied Optics, 19 [1980], pp 3729-3734).

The Faraday effect has been used to determine the magnetic field distribution in plasmas (H.J. Kunze in Plasma Diagnostics, W. Lochte-Holtgreven, ed., North-Holland, Amsterdam, 1968) for which the rotation is determined from

$$\phi = 2.6\times10^{-17}\lambda^2\int n\underline{B}\cdot d\underline{l} \qquad (2)$$

where lengths are in centimeters, $\underline{B}$ is the magnetic induction in gauss, and n is the electron density in cm^{-3}. Normally, one combines Faraday rotation measurements with interferometric measurements of $\int ndl$ to determine the magnetic field. In plasmas, unlike solid materials, the rotation increases with wavelength so that microwave radiation rather than light is appropriate for low-density plasmas. Researchers at the Naval Research Laboratory have combined rotation measurements of Nd-glass laser light with density profiles from code simulations of ablation plasmas to determine the self-magnetic field distribution in laser-irradiated targets (J.A. Stamper, E.A. McLean, and B. Ripin, Physical Review Letters, 40 [1978], pp 1177-1181).

During the last few years, publications have described the fundamental ideas and theory of Faraday rotation of laser light in optical fibers for application to high-current measurements in research and industry. From Equation (1), the rotation experienced by light guided in a single- or multiple-turn loop of optical fiber is proportional to the current which threads the loop. The loop is insensitive to fields associated with external current flow because rotation produced by it on one side of the coil is canceled by rotation in the opposite sense on the other side.

These desirable properties make the optical loop perform in a manner similar to the electromagnetic Rogowski loop--a solenoidally wound toroid sensitive to

the rate of change of current passing through the hole. The optical analogue has additional advantages. Because the sensing and signal-transfer components are dielectric, current can be measured at high voltage, in environments with close-to-breakdown field strengths, and where electrical insulation problems exist. The optical device is self-integrating because the rotation is proportional to I rather than dI/dt. Finally, as the bandwidth of the optical components is effectively infinite, the frequency response of the detector is limited only by that of the rotation-sensing electronics.

Dr. Cor Bobeldijk, experimental group leader in the SPICA toroidal pinch program at the Institute for Plasma Physics at Rijnhuizen, Nieuwegein, the Netherlands, described to the author an optical current loop to be installed in the new SPICA II device. The diagnostic is being developed for 1% accurate pulsed current measurements in the megampere range.

SPICA II is a high-β toriodal screw pinch with an elongated cross-section designed to test theoretical predictions regarding plasma stability in noncircular cross-section discharges. The optical diagnostic was chosen to measure the induced toroidal current for two reasons--both related to the advantages mentioned earlier. First, the conducting wall of the device in which the diagnostic is to be embedded will be at high voltage because it serves as the transformer primary that induces the toriodal plasma current. Second, because of the noncircular cross-section, it is difficult to determine the total current from local magnetic field (B-dot) measurements.

In the simplest configuration to be mounted in the experiment, the diagnostic light train consists of a He-Ne laser, a polarizer, a special optical fiber with about 2 m of its length embedded circumferentially in the conducting wall, a beam-splitting Wollaston prism, two light detectors to measure the sine and cosine of the rotation angle, and associated detector electronics. Maximum sensitivity and linearity are obtained by adjusting an angle of 45 degrees between the prism and initial plane of polarization. The two components entering the detector then have amplitudes

$$J_{1,2} = \frac{J_0}{2}(1 \pm \sin 2\phi), \tag{3}$$

where J_0 is the intensity incident on the prism. The electronics can then be used to derive a signal from which the current can be inferred.

$$S = \frac{J_1 - J_2}{J_1 + J_2} = \sin 2\phi \tag{4}$$

Although the principles outlined above are simple, there are several special technological requirements associated with current detection by optical rotation in fibers (H. Aulich et al., Applied Optics, 20 [1980], pp 3735-3740). The fibers themselves must be capable of transmitting polarized light with low attenuation and depolarization. The Verdet constant must assure sufficient rotation for a high signal-to-noise ratio (SNR). Birefringence and extraneous rotation caused by bending, twisting, and stress on the fiber must be minimal.

Specially fabricated single-mode (HE_{11}) fibers are preferred because, in principle, they have a single well-defined phase velocity and polarization state allowing small variations to be observed readily. The use of relatively short lengths of single-mode fiber in current measurement applications (as compared with several kilometers in communications applications) poses a special problem. Linearly polarized light is guided through the core while arbitrarily polarized light can be guided in the SiO_2 cladding. In communications, the cladding modes are strongly attenuated by the great length. In a current diagnostic, these modes may introduce serious measurement errors. Adding an absorbing black dye to the silicone used for the outer sheath of the fiber can prevent excitation of cladding modes.

Birefringence and extraneous rotation can be eliminated effectively in single-mode fibers; during fiber drawing a permanent twist of a few turns per meter restores an average circular symmetry to the waveguide structure (A.J. Barlow et al., Applied Optics, 20 [1981], pp 2962-2968). The Rijnhuizen group uses twisted fibers manufactured by the Univ. of Southampton, UK. The fibers have a GeO_2/SiO_2 core ~ 4-μm diameter, a B_2O_3/SiO_2 cladding of 16.5-μm diameter, and a protective outer layer of quartz.

Because of the small core diameters of single-mode fibers, a stable, high radiance light source is needed to achieve high SNR. The dependence of V on wavelength requires that the source be monochromatic. A 5-mW He-Ne laser operating at 633 nm was chosen for the

SPICA II diagnostic. The source satisfies the above requirements and provides adequate rotation for the chosen fiber material. The light source, input coupler, optical fiber, output coupling lens, prism analyzer, and detectors must be assembled so that mechanical shock, vibration, or temperature cycling will not alter coupling of light into the fiber. Practical problems associated with system assembly were encountered in preliminary Rijnhuisen experiments conducted by R. Woltjer. Techniques were developed for handling the fibers without breakage, for perfect cutting of fiber end faces, and for their coupling to the light source. The trials resulted in direct current measurements of 17 kA with 0.5% accuracy.

A laboratory prototype of a magnetooptical current transformer for commercial power transmission applications has been developed at the Forschungslaboratorien der Siemens AG, Munich. The optical diagnostic satisfies the requirements to measure currents at high voltage and high accuracy (for metering and billing), and it has the frequency response necessary for operating protective devices. At room temperature and 100-kV standoff, the device measured currents in the 50- to 1200-A range with 0.24% accuracy using a 20-turn coil (H. Harms and A. Papp, Applied Optics, 19 [1980], pp 3741-3748).

This writer believes that an area that requires investigation is the application to current measurements in high-power dielectric pulse line generators. These multi-MV, multi-MA pulsers create electromagnetic radiation, charged-particle beams, and x-radiation used in the laboratory to simulate nuclear weapons effects for hardness testing. Measurements have usually been limited to ground-side currents because of the very high voltages employed. Such measurements are often unsatisfactory because they cannot be used to determine the spatial distribution of current flow in metal surfaces and bounding vacuum regions. Optical Rogowski loops could be mounted directly on high-voltage electrodes in vacuum or on structures in water and oil sections to provide detailed current distributions. Measurements on the 10-ns timescale, which characterizes the fastest current variations, should pose no difficulties. A potential problem may be fluorescence induced in the fiber by the strong x-ray environment. Mechanical shock insulation may also be required to prevent fiber breakage and to maintain good optical linkage. However, even with difficulties, the optical current diagnostic may be developed into an important new tool of pulsed-power technology.

D. Mosher

NEW CONCEPTS IN PARTICLE ACCELERATION

Elementary particle physicists use high-energy particle beams to probe atomic nuclei and test modern field theories. The highest energy interactions currently produced by laboratory accelerators allow one to resolve subatomic structure into quarks and leptons and to test predictions of theories that unify electromagnetic and weak nuclear forces. Determination of unknown finer structure and evaluation of models in which the strong nuclear force is unified with the weak and electromagnetic forces may require probe beams with orders-of-magnitude greater energies than now available. However, conventional accelerators are rapidly approaching technological and economic limits. Thus, new concepts must be developed if large increases in particle energy are to be achieved.

To discuss means of achieving such a breakthrough, about 90 physicists (including 18 speakers) met at New College, Oxford, between 27 and 30 September 1982. The conference was entitled "The Challenge of Ultra High Energies." The importance of new accelerator concepts to the future of high-energy physics was demonstrated by the large representation of senior physicists (including several laboratory directors) from the US and Europe. Although motivated by the desire to extend the frontiers of elementary particle physics, many of the acceleration techniques considered have potential defense-related, directed-energy applications.

Conventional Techniques

Conventional technology uses radio-frequency (r.f.) electromagnetic waves to accelerate bunches of charged particles. The highest energy beams are produced in 500-GeV proton synchrotrons about 6 km in circumference at CERN near Geneva and Fermilab near Chicago. In these devices, magnets with increasing field strengths confine the beam to a fixed circular path as it gains energy from r.f. standing waves set up in cavities between the magnets. Electron energies achievable in circular devices are limited to lower values because of losses to synchrotron radiation (see FSN 36-12:345-348 [1982]). The highest energy electron beams are currently

produced in the Stanford linear accelerator, a 3-km long, 24-GeV device. In the linac, a travelling electromagnetic wave is synchronized with the comoving electron beam by guide structures so that the charge bunches always experience acceleration in the same direction. Currently in development at CERN is a vast 27-km circumference storage ring in which counter-rotating 100-GeV electron and positron beams are planned.

In the opening lecture, A. Salam (Imperial College, London) set a goal that future accelerators should attempt to achieve in order to uncover possible new phenomena. Although the "standard" model (for which he and S. Weinburg are credited) predicts no new physics until the grand-unification energy of 10^{14} GeV is reached, relaxation of assumptions might lead to new particles from the collision of opposed beams with about 100 TeV (1 TeV = 1000 GeV) in the center of mass. The figure, about 100 times the energy currently achievable, was adopted by conference participants as an objective for evaluation of new accelerator concepts.

G.A. Voss (Deutsches Elektronen Synchrotron [DESY], Hamburg) described the limitations of conventional r.f. acceleration for future large machines. He stressed that limits were chiefly economic and developed scaling laws for costs of various machine configurations. There are two types of costs to consider: capital costs for tunnel construction and hardware installation, and operational costs, which are dominated by power consumption. For a proton synchrotron, the radius of the tunnel scales like E/B, where E is the particle energy and B is the magnetic field strength. For a 2-T field, the proportionality constant is 400 GeV/km. Then, as both construction costs and magnet-power consumption scale like the radius, the total accelerator cost will be roughly proportional to beam energy. The higher (factor of 2 to 5) magnetic fields available with superconductors can reduce the radius, but savings are offset somewhat by power consumption of the cryostats.

The cheapest installation (a sewer pipe on a desert surface) would cost about $3,200 per meter of length. Even with high magnetic fields, a 100-TeV machine would have a minimum cost of several billion dollars. Because of synchrotron radiation losses, costs for lepton colliding rings scale like E^2, so that linear accelerators become attractive at high energy because size and cost again scale like E. Currently, linacs operate with accelerating electric fields of about 10 MV/m. Even if they can be made to operate at 100 MV/m, a 100-TeV device would be 1000-km long!

New Concepts

It is clear from the above considerations that viable new acceleration techniques must involve much higher electric field strengths than conventional technology to make future accelerators of manageable size. Although the super-high particle energies with which the conference was concerned are not of interest for defense applications, the required high electric fields are crucial to any mobile platform on which a directed-energy system might be based. For either application, stresses in the gigavolt per meter regime are desirable.

J. Lawson (Rutherford Appleton Laboratory, Didcot, Oxfordshire) classified the various concepts according to the way the accelerating field is produced and provided guidelines with which to evaluate them. Because of the anticipated small reaction cross-sections at high energy, constraints in addition to cost and particle energy are important. High current beams of high brightness will be required to achieve reasonable event statistics and are important for military applications.

For the most part, proposed acceleration techniques involve the large electric fields associated with intense laser and charged-particle beams. Lawson catagorized such drivers according to whether the accelerating fields were produced in vacuum with no free charges, vacuum with free charges, or a medium. The rest of this article highlights acceleration techniques in these three categories.

Vacuum Field Acceleration

Although the electric field strengths of focused laser beam radiation are very high, a propagating beam in free space cannot be used to accelerate charged particles. Electromagnetic radiation, moving at the speed of light in vacuum, is always faster than the charged particle so the wave will move out of phase with the particle. Also, the electric field vector is transverse to the direction of propagation and therefore cannot accelerate comoving charged particles.

One solution is to modulate the particle's path with a static, alternating magnetic field. The resulting transverse wiggle in the particle orbit produces a component of velocity in the electric field direction, thereby allowing energy to be removed from the wave. This first catagory concept, discussed by C. Pellegrini (Brookhaven National Laboratory, New York), is the inverse mechanism of the free electron laser. An advantage of the technique is that no structures are required for which

surface breakdown or plasma formation will limit allowed field strengths. However, the energy of electrons or positrons accelerated by the technique will be limited by synchrotron radiation produced by the oscillating orbit.

If the wavelengths of the radiation and wiggler field are λ and λ_0 respectively, then acceleration occurs when

$$\lambda = \frac{\lambda_0}{2\gamma^2}(1+\kappa^2) \quad (1)$$

where γ is the relativistic factor and

$$\kappa = \frac{eB\lambda_0}{2\pi\sqrt{2}mc^2} \quad (2)$$

Thus, to maintain synchronism as particle energy increases, either λ_0, κ, or both must change. Pellegrini considered several numerical examples. For a laboratory experiment, he chose a 1-μm laser power of 10^{13} W with a 1-ns duration focused to 0.25-cm diameter over an interaction length of 39 m. Synchronism would be achieved either with λ_0 = 10 cm and B varying from 0.31 to 3.8 T or B = 1 T with λ_0 varying from 3.8 to 23 cm. For an injected electron energy of 250 MeV, his calculations resulted in about 4-GeV final energy or a 100-MV/m average accelerating field.

R. Palmer (also of Brookhaven) described a near-field category 1 laser accelerator in contrast to his associate's far-field concept. Near-field devices use dielectric or conducting structures to shape the adjacent electromagnetic field such as to accelerate a charged particle beam. Palmer described a diffraction grating contained in a mode-resonant cavity that supported an evanescent wave within one wavelength of the grating surface. Although the technique could support very high field gradients, perhaps 10 GV/m, the surface of the grating would be destroyed following each acceleration pulse. Palmer suggested that a renewable surface one skin-depth thick (about 0.1-μm thick for 10-μm laser radiation) would have to be supplied. This is not a trivial matter because the structure must be configured to a small fraction of a wavelength over the length of the accelerating region.

Another problem is that the accelerating field exists only within one wavelength of the grating surface so that a very small (10-μm diameter), precisely collimated charged particle beam is required. Of course, if achievable, such a beam would have a desirable high luminosity. Palmer calculated that a 20-kJ laser of 30-ps duration might be sufficient to achieve 10-GV/m accelerating fields. Pulses of such duration or shorter are needed to limit plasma expansion from the grating surface to 1/10 wavelength or less.

M. Tigner (Cornell Univ.) developed scaling laws for near-field accelerators with driving radiation ranging from the microwave to laser light wavelengths. He was concerned with reusable guide structures and so limited accelerating fields to values below the melt threshold. The limiting field scaled like $\lambda^{-1/8}$ with values of 400 MV/m at λ=10 cm and 1.3 GV/m at 10 μm. With respect to driving sources, Tigner indicated that efficient gigawatt microwave generators based on free electron lasers or relativistic electron beam tubes must be developed. Although such power levels are easily achieved with infrared lasers, no present laser has high enough spatial or temporal coherence to establish the accelerating field over the required lengths.

Acceleration With Charges in Vacuum

Preeminent among Lawson's second category concepts was the wake field accelerator described by T. Weiland (DESY). The idea was widely regarded as promising by the conference participants. Highly relativistic electron bunches (such as those created in the DESY storage ring) generate a wake of electromagnetic radiation as they propagate. Properly designed structures might concentrate the wake electric field to high values so that trailing, smaller bunches can be accelerated to energies much higher than that of the primary electron beam. The structure-coupled, two-beam system acts as a transformer, transferring energy from a low-energy, high-current primary to a high-energy, low-current secondary.

Weiland and Voss performed calculations and numerical simulations for the case of annular cylindrical electron bunches passing around plates with a central hole (see Figure 1). With proper timing, the wake field implodes radially inward to the central hole and arrives on axis coincident with the trailing secondary bunch. The annular beam, produced by a ring cathode or electron ring accelerator, is guided and confined by a solenoidal magnetic field.

A two-dimensional electromagnetic code was used to evaluate the wake field accelerator for a 5.5-GeV primary beam injected into an accelerating structure of 6-cm outer radius with a 2-mm annular

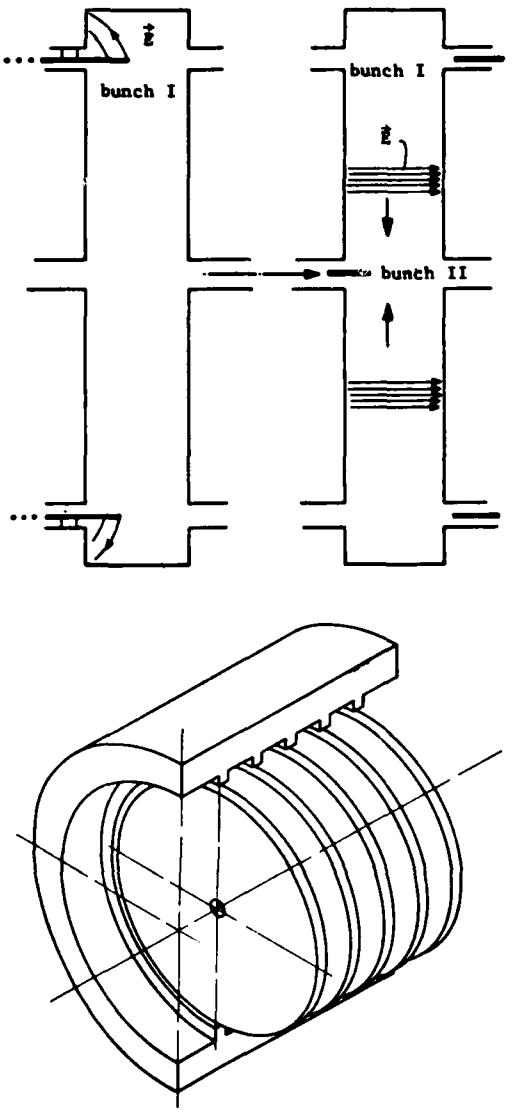

Figure 1. Wake field accelerator concept.

slot and a disc separation of 4 mm. A central gradient of 170 MV/m was calculated to appear on axis about 290 ps after passage of the annular beam front. Since the annular self fields slowed the primary beam at a rate of 17 MeV/m, a wake field transformer gain of 10 was achieved. With 6×10^{12} particles per primary bunch and 10^{11} per secondary bunch, a 550-m-long accelerator would slow the primary beam to 0.5 GeV and accelerate the secondary beam to 56 GeV.

The choice of a circular-cylindrical transformer was based on the available computational tools rather than any inherent advantage of the annular geometry. Weiland described an elliptical cross-section structure in which primary and secondary solid cylindrical beams pass through the foci, and a system in which the annular beam is replaced by a number of small diameter solid beams arranged around the secondary. Both geometries avoid the substantial difficulties associated with creation of an annular primary.

Although the analysis for the wake field accelerator is straightforward and convincing, the technique is probably limited to electric-field strengths of a few hundred megavolts per meter. However, the accelerating structures are simple and inexpensive, and should perform reliably. Breakdown limits are probably less severe than for other near-field structures because high field strengths occur only over a limited area and for a short time. A major concern of the conference participants was the degrading effects of the self-fields on the primary beam. The calculations presented assumed a rigid slug of charge, unaffected by passage through the annular slots. A self-consistent simulation in which coupled beam and field dynamics determine longitudinal and transverse spreading, displacement, and stability would answer many of the doubts associated with the concept.

Another category 2 concept involving one beam accelerating another was described by A.N. Skrinsky (Novosibirsk). He presented the idea of a proton klystron in which a part of the bunched proton beam of the Super Proton Synchrotron (SPS) is extracted and run through a long linac structure. The proton beam passage induces an r.f. field which can accelerate an electron, muon, or pion beam in the same structure. Because of the slightly higher velocity of the secondary light particle beam, phase-shifting structures would be required. However, D. Keefe (Lawrence Berkeley Laboratory) felt that this would not be difficult at the high relativistic factors encountered.

Skrinsky believes that average gradients of 100 MV/m are possible so that with 3-MJ energy available in the proton beam, 5-TeV secondary beam energies could be achieved with a 50-km-long structure. At first glance, Skrinsky's idea appears to be a case of the cart leading the horse--i.e., using heavy particles to accelerate light ones. However, since the SPS proton beam already exists, the power source for a 5-TeV electron accelerator may already be at hand. Dr. Balakin (Novosibirsk) described an electron wake field accelerator using the klystron structure described by his associate.

Because electrical breakdown would occur only after the ion and trailing electron bunches had passed a given structure, Balakin estimated that 3 GV/m might be possible.

Acceleration schemes based on the wake field and proton klystron concepts have no clear application to mobile platforms because a large, heavy-particle accelerator is needed to generate the driving beam.

Acceleration in Media

The category 3 scheme which attracted the most interest at the conference was the laser beat-wave accelerator presented by T. Tajima (Univ. of Texas, Austin). Theoretically, accelerating electric fields in the 100-GV/m range appear possible with the technique. Two laser beams are injected into a plasma with a difference frequency $\omega_0-\omega_1$ equal to the electron plasma frequency ω_p. The beating of the two light waves gives rise to large amplitude plasma oscillations (plasmons) with a phase velocity close to that of light. The process can also be regarded as nonlinear optical mixing or forward Raman scattering. Electrons become trapped in the electrostatic wells of the plasma oscillation and can then be accelerated to the wave phase velocity. Tajima noted that the 10^{13} W/cm² power density achievable with pulsed charged-particle beam technology limits the accelerating electric field of excited oscillations to about 1% of what might be achieved with glass-laser radiation at 10^{18} W/cm².

In the limit of small ω_p/ω_0, the plasmon phase velocity is equal to the electromagnetic-wave group velocity and is given by

$$(3) \qquad V_p = c[1-(\omega_p/\omega_0)^2]^{\frac{1}{2}}$$

The maximum electrostatic field can be determined from Poisson's equation by assuming a unity density fluctuation in the wave

$$(4) \qquad E = m\omega_p c/e$$

By Lorentz transforming to the wave frame to determine the height of the potential well and then transforming back to the laboratory frame to calculate the maximum energy of accelerated electrons, one obtains

$$(5) \qquad W = 2(\omega_0/\omega_p)^2 mc^2$$

The time and length required to accelerate electrons to this value are given by

$$(6) \qquad t_a = 2(\omega_0/\omega_p)^2/\omega_p \; ; \; L_a = ct_a$$

For 10^{18} W/cm² of 1-μm laser radiation penetrating a plasma of 10^{18} cm^{-3}, E is calculated to be 100 GV/m, and electrons can be accelerated to GeV energies over a 1-cm length.

Computer simulations of the beat-wave mechanism using a self-consistent relativistic electromagnetic code (one-dimensional spatial, three-dimensional velocities and fields) were presented by D. Sullivan (Mission Research Corp., Albuquerque, NM). The simulation agreed with analysis in that the electrostatic field grew to the value predicted by Equation (4) in a time of $30/\omega_p$. C. Joshi (UCLA) described experiments aimed at demonstrating the beat-wave mechanism. One experiment used CO_2-laser radiation at 9.6 and 10.27 μm with a difference frequency corresponding to a plasma density of 6×10^{16} cm^{-3}. The plasma was generated by an arc in 4-torr argon. The proper density was achieved over a 2-cm length, and irradiation of the volume at about 10^{10} W/cm² was achieved with an f/12 focusing lens. Thomson scattering measurements indicated electron density fluctuations of about 0.5%, in agreement with theory for the low-intensity radiation used, at which level no significant acceleration of electrons was expected and none was observed.

Two other experiments described by Joshi attempted to demonstrate beat-wave acceleration by the forward Raman instability. For this mechanism, the second (ω_1) wave grows from thermal noise rather than being imposed. High intensity (10^{15} W/cm²) CO_2 radiation and blue light from a frequency-tripled Nd-glass laser were focused on solid targets in two separate experiments. The results of both were inconclusive with respect to creation of the ω_1 wave and accelerated electrons.

Acceleration With Intense Relativistic Electron Beams

The remaining talks reviewed category 2 and 3 collective ion

acceleration techniques using intense relativistic electron beams (IREBs) produced with dielectric pulse line generators. As the concepts have been researched and reported on for many years, they are described here only briefly (see for example, Olson and Schumacher, Collective Ion Acceleration, Springer Tracts No. 84 [1979]). A. Sessler (Lawrence Berkeley Laboratory) broadly reviewed all the collective effects accelerator (CEA) concepts. He defined them as techniques by which the accelerating electric field is produced by charged particle bunches, which are, in turn, controlled by external fields. Except for the laser beat-wave accelerator, CEAs involve IREBs characterized by 1- to 10-MeV energies, 10- to 100-kA currents, and 10- to 100-ns durations. Although pulsed power technology can produce beams with much higher currents, low-impedance beams have large self fields, which presumably preclude sufficient external control for accelerator applications. Scaling Poisson's equation, Sessler derived an expression for the maximum electric field for CEA accelerators

$$E(\mathrm{MV/m}) \simeq \frac{6I(\mathrm{kA})}{\beta l(\mathrm{cm})} \tag{7}$$

In Equation (7), $\beta=v/c$ for the beam, and l is the characteristic gradient length. For the above beam parameters and $l=1$ cm, a maximum field of a few hundred megavolts per meter is predicted.

V. Schumacher (Max Planck Institute, Garching) reviewed research with the electron ring accelerator (ERA). The most popular form of this CEA technique involves establishing an electron ring in a solenoidal magnetic field, compressing it by increasing the field, and then accelerating the ring longitudinally with a radial component of magnetic field. Ions trapped within the electrostatic well of the ring are accelerated with it. Experiments at Garching demonstrated longitudinal acceleration to 4×10^{15} cm/s^2 with hydrogen and helium loaded rings. Schumacher described results of Soviet ERA experiments at the Institute for Nuclear Research, Dubna. The work demonstrated magnetic acceleration to 5 MeV/nucleon for $6\cdot10^{11}$-particle N^{3+} and $2\cdot10^{11}$-particle Xe^{13+} beams (V.P. Sarantsev et al., "Development of Collective Acceleration Methods at the Joint Institute for Nuclear Research," in High-Power Beams 81, ed., H.J. Doucet and J.M. Buzzi [Palaiseau, France: Ecole Polytechnique, 1981], pp 691-698). These successes have led to construction of a 20-MeV/nucleon ERA injector for a heavy-ion accelerator at Dubna.

M. Reiser (DSI, Darmstadt, on leave from the Univ. of Maryland) reviewed beam-front acceleration techniques. This CEA concept involves propagation of an IREB with a current in excess of the space-charge limit for propagation in free space. High electron densities at the stagnating beam front produce an accelerating electric field of magnitude

$$E(\mathrm{MV/m}) \simeq \frac{2}{r}\left(\frac{\gamma I}{I_0}\right)^{\frac{1}{2}} \tag{8}$$

where r is the beam radius in meters and I_o = 17 kA. For Sessler's beam parameters, Equation (8) yields 1 GV/m.

Reiser described two methods for controlling the velocity of the beam front so that particles could be accelerated from low energy. The first, the Ionization Front Accelerator (IFA) developed by C. Olson (Sandia National Laboratory, Albuquerque, NM) uses a light-pipe array terminated transverse to a gas-filled drift chamber to produce a controlled ionization for neutralizing the IREB head (Figure 2). The second involves launching an electromagnetic wave along a helical conductor wound about the electron beam path. The longitudinal velocity of the wave in the drift chamber and therefore the ionization-front velocity are controlled by the pitch of the helix. Reiser concluded by pointing out that CEA techniques short circuit the usual power train for conventional particle acceleration (power source → electron beam [klystrons, etc.] → r.f. → accelerated particles) by eliminating the r.f. stage. However, beam control, reliability, and reproducibility must be improved before conventional sources can be replaced.

J. Nation (Cornell Univ.) reviewed research using waves impressed or grown on IREBs in which ions can be trapped and accelerated. He described slow waves, which could be controlled by external field and beam guide structure variations so that acceleration from low energy could be achieved. For beam wave accelerators of this type, a practical limit to the achievable electric field is determined by electron self-trapping in the wave. At low phase velocities,

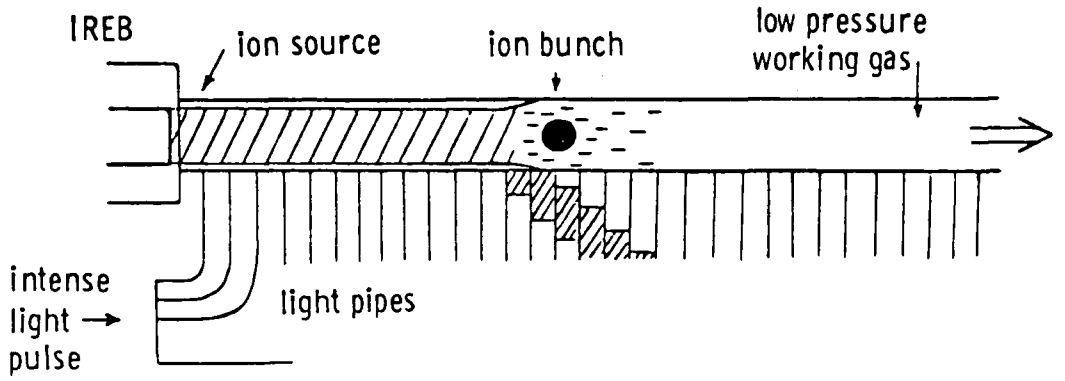

Figure 2. Ionization front accelerator.

perhaps 200 MV/m is achievable. At high phase velocities, the electric field decreases as $1/\gamma$ so that acceleration to very high energies would be difficult with slow-wave structures. However, fast, nonlinear beat waves produced by modulating the beam with a rippled wall or magnetic field may be useful for high energies.

D. Keefe (Lawrence Berkeley Laboratory) recapped the collective acceleration concepts on the last day of the conference. He pointed out that research has primarily addressed acceleration of ions to nonrelativistic velocities. For such efforts, techniques for control of the driver velocity represent major problems. For charged particle beams that are already at close to light speed, the driver velocity need not match the accelerated particles' speed precisely. CEAs can then be modularized and staged, thereby making practical designs easier to realize than for low energy acceleration.

Persons interested in learning about "The Challenge of Ultra High Energies" in greater detail can contact J. Mulvey, Department of Nuclear Physics, Univ. of Oxford. The author is indebted to Denis Keefe for his insights and comments.

M. Mosher

PSYCHOLOGY

THE 20TH INTERNATIONAL CONGRESS OF APPLIED PSYCHOLOGY

The 20th International Congress of Applied Psychology was held at the Univ. of Edinburgh, Scotland, 25 through 31 July 1982. The Congress, organized by the International Association of Applied Psychology (IAAP), was attended by about 1,500 psychologists from more than 60 countries.

The program consisted of 20 invited keynote addresses with simultaneous translation, 80 symposia and workshops, and 600 "interactive poster sessions" covering professional and cross-cultural issues, educational psychology, ergonomics, counseling and clinical psychology, industrial-organizational psychology, psychometrics, environmental psychology, and applied social areas. Perhaps the best-attended invited lectures were those by Chris Argyris (US), "Problems in Producing Useable Knowledge for Implementing Liberating Alternatives"; Paul Kline (UK), "Psychometrics: A Science with a Great Future Behind It?"; and Philip E. Vernon (Canada), "Abilities of North American Orientals--A Study in Acculturation."

Often the most innovative presentations were the "interactive" poster sessions; authors were invited to be available for about 3 hours. The sessions replaced the oral delivery of prepared papers and provided the audience and presenters an opportunity informally to discuss research interests. Despite the different languages represented, informal feedback about the interactive sessions both from presenters and from members of the audience was overwhelmingly positive.

A full program of professional visits for psychologists with various applied interests was arranged. The Scottish and Newcastle Brewery provided seminars on topics such as personnel problems with alcoholism, employee hiring practices, and marketing and attitude surveys. There were tours of

several prisons and institutions for men, women, and youth offenders. Human factors psychologists were interested in the British Rail Signalling Centre, which is attempting to make railway signals more effective. There were also visits to psychiatric and rehabilitation hospitals, the Bank of Scotland's Staff Training Centre, and the Open Univ. in Scotland.

There were exhibits by the American Psychological Association, whose PsycInfo computer system was used to demonstrate the sharing of information from large data bases; the British Psychological Society; test publishers; book publishers; and psychological equipment manufacturers from the US, the UK, Italy, France, and the Netherlands.

During the week of the Congress, several other international organizations participated in jointly sponsored scientific sessions, social hours, and business meetings. The groups included the International Union of Psychological Science, the Interamerican Society of Psychology, the International Council of Psychologists, the International Test Commission, and the International Association for Cross-Cultural Psychology.

During the Congress, the IAAP Executive Committee approved three new divisions and divisional presidents: Clinical and Community (Sheldon Korchin, Univ. of California, Berkeley), Gerontological Psychology (Robert Morgan, California School of Professional Psychology), and Instructional, Educational, and School Psychology (Wilbert McKeachie, Univ. of Michigan). Existing divisions include Organizational Psychology (Peter Drenth, Free Univ. of Amsterdam), Psychological Assessment (Iraj Ayman, Iran, now in Chicago), Environmental Psychology (Kenneth Craik, Univ. of California, Berkeley), and Psychology and National Development (Jai Sinha, ANS Institute, Patna, India).

There are still a few copies of the Scientific Program, the Abstracts, and a limited edition of prints of Old Edinburgh published especially for the Congress. For information, write to the Congress Secretariat, CICL, Univ. of Edinburgh, 16 George Square, Edinburgh EH8 9LD. The publication of selected proceedings is being planned. The next International Congress of Applied Psychology will be held in Jerusalem, Israel, in 1986.

C. White
Advanced Research Resources Organization
Washington, DC

SPACE SCIENCE

AGGRESSIVE EUROPEAN POSTURE IN X-RAY ASTRONOMY

It has been 25 years since Sputnik I was launched, marking the beginning of space exploration. Striking scientific discoveries have occurred in this period, notably in the satellite exploration of the solar system and new observations of stellar radiation spectra in high energy (x-ray and gamma ray) regimes.

The development of x-ray astronomy has been largely through US initiatives, culminating with the Einstein Observatory Mission that terminated in 1981. At this point, however, the US program seems to be in a deep stall, and soon the lead in the field will transfer to the Europeans (see the recent article "European X-ray Astronomy" by H. Gursky, ESN 36-7:164-166 [1982]).

This article reports on highlights of a symposium--Very Hot Astrophysical Plasmas, A European Workshop--held in Nice, France, 8 through 10 November 1982. The purposes of the symposium were to review areas of astrophysics that relate directly or indirectly to x-ray phenomena and to review current and stimulate future mission activity in x-ray astronomy.

The program consisted of invited speakers and contributed poster papers that were available for the complete meeting and summarized by rapporteurs. The French, Italians, British, and Dutch were the major contributors. The speakers were European, except for two Americans and one Japanese. Of the 130 participants, about 50 were from France.

The opening talk of the symposium was given by K.A. Pounds (Univ. of Leicester, UK) on "X-Ray Astronomy in the 1980's." Eleven x-ray satellite missions took place in the 1970s, culminating with the Einstein Observatory that advanced the field into the mainstream of astrophysics. Only one x-ray mission (by the Japanese) is currently operative, but six or seven x-ray missions may take place in the 1980s. Only one, a timing mission known as XTE, would be by the US. A second Japanese mission is scheduled for launch in early 1983, and the European satellite EXOSAT, delayed by the last Arianne failure, may be launched in the summer of 1983.

Other approved x-ray missions scheduled for launch in the 1980s are the German satellite ROSAT, a third Japanese satellite, India's first effort in the field, and the Italian mission

SAX. The mission X-80 has been proposed to the European Space Agency (ESA) for possible new start status. The Advanced X-ray Astrophysics Facility (AXAF) was given the highest recommendation by the US astronomical community, but NASA's budgetary problems precluded timely approval of the mission. It now appears that AXAF will achieve new start status no sooner than 1986, with a launch in the 1990s. Pound concluded his talk by describing a project the British are discussing: a low-cost (about $75 million) mission to do x-ray spectroscopy. The mission would complement efforts such as AXAF that would likely be dedicated to small regions of the sky.

The exciting sequence of discoveries in x-ray astronomy has exceeded expectations because the abundance of astronomical x-ray emitters was not at all anticipated. It is now realized that x-rays are a powerful diagnostic tool for probing plasma regions of outer space. X-radiation is characteristic of stellar atmospheres and coronae, binary systems, supernova remnants, clusters, galaxies, and other hot plasmas. Future advances in the subject will emphasize spectroscopy (to identify the x-radiating elements), timing (since many spectra are highly time dependent), and improved spectral resolution (down to a fraction of an angstrom). With improved experimental data of this sort, theorists will be able to make fundamental advances on questions relating to stellar structure and evolution, dynamics, and relativity.

R. Mewe (Utrecht, Netherlands) spoke on the "Physics of Hot, Optically Thin, and Thermal Astrophysical Plasma." The spectral characteristics of a cosmical plasma are neatly characterized by its temperature. At very high temperatures ($\gtrsim 10^{8}$ °K) the plasma is fully ionized and the x-ray spectrum is due to bremsstrahlung. At lower temperatures ($\lesssim 10^{7}$ °K) the x-ray spectrum acquires structure (lines) that relates to the dynamics and dispersion of the plasma. The thermodynamic state of x-radiating plasma is characteristically non-equilibrium and time dependent, and both the plasma temperature and density are time dependent variables. Because the radiated spectral lines depend strongly on the temperature, adequate theoretical descriptions are possible only if the state of the radiating plasma can be specified experimentally. In this regard, the improved spectral sensitivity of EXOSAT over Einstein should resolve quite a few extra lines, particularly at smaller wave lengths, that are needed to understand the plasma dynamics at high energies.

Presentations on supernovae and supernova remnants were given by N. Panagia (Bologna, Italy) and H. Itoh (Univ. of Cambridge, UK, on leave from Univ. of Kyoto, Japan). Supernovae have been extensively observed in recent years. Type I supernovae have rather ordinary black body spectra extending from radio through gamma ray wavelengths. Type II supernovae were first observed in 1978 and, contrary to Type I, have an excess of ultraviolet (UV) over visible radiation in their broad band spectra. Models are being developed to identify physical absorption and emission processes that would account for the observed spectra. For example, locating an emission zone behind an absorbing layer works better for Type II. Progress in the field requires better statistics at all wavelengths. Type I, which is a more homogeneous class, requires better coverage in the infrared and UV to help clarify the emission processes. Type II requires high resolution UV spectroscopy and especially x-ray spectroscopy to identify processes, determine the abundances of metals, and probe the dynamics. With adequate resolution, the kinematics of the supernova shock front could be studied. Itoh emphasized the great variety of supernova remnants, which are not simply characterized by blast waves or other preconceived notions, and are far from understood.

In the discussion of stellar and galactic winds, mass loss rates and models were emphasized. Current models of wind acceleration essentially draw upon either of two mechanisms: dynamical expansion (similar to the supersonic expansion of a gas through a nozzle) or radiation pressure. Astrophysical wind models are spherically symmetric and do not explicitly include magnetic fields. Improved x-ray measurements would relate to temperature, column density, and emission rates of the expanding plasma. The information would help sort out current wind theories and promote the field.

Several papers dealt with optically thick systems that included white dwarfs, neutron stars, and possibly black holes. Most galactic x-ray sources are believed to consist of such compact objects accreting gas from a companion star in a binary system. An accretion disc forms around the neutron star with mass flow rates near the speed of light. A dynamical balance is established between the accretion mass flow and the opposing radiation pressure

due to Thomson scattering. J. Van Paradijs (Univ. of Amsterdam, Netherlands) pointed out many contrasting properties of low- and high-mass binaries. Massive binaries are characterized by a luminosity ratio (x-ray to optical) less than 10, a hard x-rav spectrum (kT > 15 keV), no bursters, many pulsars, and large stellar winds promoting mass exchange. Low mass x-ray binaries have a luminosity ratio larger than 10, a soft x-rav spectrum (kT ≈ 5 keV), many bursters, few pulsars, and a moderate mass transfer in order not to cut off the x-ray emission.

R. McCray (Univ. of Colorado) emphasized the importance of high resolution x-ray spectroscopy, particularly with Fe, to advance the field. A satellite such as the proposed X-80 would provide new information on the physical conditions of accreting sources. Such sources are intrinsically complicated, and measurements are needed to pick out density and temperature components separately. Polarization modes of pulsar radiation and the relative phases of soft and hard x-ray emissions are needed to model the spatial structure of the radiating plasma (e.g., pencil or fan shaped) and to begin to unravel some of the dynamics. Effects due to rotation and magnetic fields are probably crucial to much of the dynamics. For example, low mass binaries do not pulse perhaps because of old age and no remnant magnetic field.

Galaxies and clusters of galaxies were discussed by A.C. Fabian (Univ. of Cambridge, England), G.C. Perola (Univ. of Rome), R. Mushotzsky (NASA, Goddard), and A. Cavaliere (Institute of Physics, Rome). Each speaker emphasized the need for the next generation of x-ray missions to address important physical questions. Fabian highlighted the study of active galactic nuclei, which are the source of most of the observed radiation. The variability of the radiation is about a day or less, corresponding to a length 10 times the Schwarzschild radius for a total mass of 10^9 solar masses. The rapid variability could result from a few small masses orbiting a large central mass. In considering the source of the radiated energy, the efficiency of mass to energy conversion (including relativistic effects and magnetic fields) implies a strong interaction of the outgoing radiation with the residual mass. Electron proton coupling, beyond simple two-body processes, should play a major role in the dynamics because the protons would carry the energy and the electrons would provide abundant radiation.

Perola pointed out that the origin of the observed x-rays is still an open question. Thermal or nonthermal processes may be involved. Going to higher energies, by observing gamma rays in the MeV or several-MeV range, would clarify the role of nonthermal processes providing the gamma rays and x-rays come from the same localized regions.

Mushotzsky reviewed some of the striking discoveries made with the Einstein Observatory and highlighted some advances to be expected from forthcoming European missions. For example, ROSAT should provide high quality data on more than 20 clusters and may discover many new low temperature clusters. The complex of Fe lines is ubiquitous in clusters. Essentially no abundance variations with respect to the sun have been seen for Fe, Si, S, and other elements found in clusters. The Fe abundance is about one half the solar value. So far, no correlation of the abundance with any cluster variable has been found. Several functional relationships were discussed relating variables such as the x-ray luminosity, temperature, density, and velocity dispersion. The overall picture is far from satisfactory, perhaps because of the "nonvirialization" of the clusters. X-rav evidence suggests there is "extra" cool gas in the center of the galaxy.

Cavaliere spoke on the "Theory of Hot Gases in Clusters" and reported results from computer simulation calculations. With densities of about 10^{-3} cm^{-3} and temperatures of about 10^8 °K, a reasonable magnetic field would be swept out into the intercluster medium. Hydrodynamic codes were therefore developed in numerical n-body simulation studies. The simulation of the evaluation of a cluster in time showed an initial cluster separating into several smaller clusters and recombining into a single, more diffuse cluster. Stationary state conditions developed rather quickly for the cluster configurations considered.

Several talks at the workshop dealt with state-of-the-art instrumentation capabilities, approved x-ray missions, and proposed missions. J. Trumper (Max-Planck-Institute, Garching) discussed the ROSAT mission, and A. Peacock (ESTEC, Noordwijk, Netherlands) discussed the delayed EXOSAT mission--projects that will be the subjects of future ESN reports.

G. Spada (Institute of Radioastronomy, Bologna) discussed the recently approved SAX mission. The satellite is planned for a 1987 Shuttle launch, would use the Italian IRIS propulsion system based on the Shuttle,

and would have a 2-year lifetime. International collaborations involving several institutes are planned. The x-ray energy range for the SAX mission is 2 to 200 keV. Mission objectives constitute a subset of those planned for the X-80 mission and include spectroscopy and spectroscopic variability of compact galactic x-ray sources, spectroscopy of cyclotron emission and absorption lines to measure magnetic fields in pulsating binaries, study of bursters and fast transients, and monitoring of long term variability. Cameras will view orthogonally to the earth-sun line from a low altitude, near-circular, and near-equatorial orbit. For many measurements, instrumental sensitivity and resolution on SAX will exceed those available in previous missions.

H. Schnopper (Danish Space Research Institute, Lyngby) spoke on "Instrumentation for the Spectroscopy of Hot Plasmas." Schnopper has been prominent in the x-ray business since the initial discovery of x-rays in space by the group at American Science and Engineering, Inc., some two decades ago. He reviewed available x-ray instrumentation and contrasted instrument capabilities. The concentrating x-ray telescope with a proportional counter at its focus has a high throughput and relatively low resolution ($\Delta E/E \gtrsim 0.2$). Solid state detectors achieve a resolution of about 3% and can be used for spectroscopy. A self-focusing array of Bragg crystals would have a low throughput but would have excellent resolution (about 0.01%) needed for detailed spectroscopic studies.

Schnopper's presentation was coordinated with A.C. Brinkman's (Space Research Laboratory, Utrecht) talk on X-80. The mission would have a variety of instruments, including a large area concentrator spectrometer, a high resolution Bragg crystal spectrometer, and several wide field cameras (34 degrees with 5-minute resolution). These instruments would be used for detailed spectroscopic studies and related plasma diagnostics. Targets for X-80 would include close binaries containing a neutron star or white dwarf, extragalactic binaries, supernova remnants, stellar coronae, active stars, x- and gamma bursters, Seyfert galaxies, quasars, clusters, and other objects.

The capabilities of X-80 place it beyond EXOSAT and make it a natural predecessor to AXAF. X-80 would be able to observe essentially everything done on Einstein or EXOSAT with greater resolution. The detector area on X-80 is a major factor; many measurements would provide order-of-magnitude improvements over Einstein or EXOSAT. Variations and time scales of many physical processes would be determined.

R. Roccia (Saclay Center for Nuclear Studies, France) discussed the CORONA mission proposed collaboratively to ESA by six European groups. The purpose is high resolution spectroscopy and improved mapping in the soft x-ray regime (<2 keV).

L. Koch-Miramond (Saclay Center for Nuclear Studies, France) described the Multi-Mirror X-Ray Observatory (MMX), which is a world-class mission proposed to ESA. High sensitivity imaging and spectroscopy would be done with an elaborate array of detectors and reflectors. High collecting power is achieved by an array of 27 telescopes providing an overall diameter of at least 3.6 m. MMX would have a collecting area 20 to 30 times greater than AXAF and have a significantly better spectral coverage from 2 to 10 keV. Sensitivity would be at least 100 times better than on Einstein, allowing MMX to study far weaker sources than found by Einstein in Fe, Si, S, and O lines. MMX would be compatible with either an Arianne 4 or Shuttle launch. Its lifetime would be more than 10 years and refurbishment or repair in space would be planned. Opportunities for international collaboration would be provided. The estimated cost of the MMX mission is $430 million, or about half that of AXAF.

Looking ahead, the European community is prepared in attitude and mission activity to assume world leadership in high energy astrophysics during the eighties. The Japanese will also become prominent in the field. US scientists will be given opportunities to be co-investigators on European missions in a process that automatically surrenders any American scientific and technological leadership. Politically, the importance of the MMX mission is that it would maintain Europe's leading role in the field during the nineties. The US would share in this lead because of AXAF.

The proceedings of the workshop will be edited by L. Koch-Miramond and T. Montmerle and published in Physica Scripta.

R.L. Carovillano

TRIBUTE TO MARCEL NICOLET

During the August 1982 meeting of the European Geophysical Society (EGS)

at the Univ. of Leeds, England, a symposium was held in honor of the distinguished Belgian scientist, Marcel Nicolet. The symposium was entitled "Structure of the Upper and Middle Atmosphere" and highlighted subjects to which Nicolet has made major contributions.

The keynote lecture by T.M. Donahue (Univ. of Michigan) reviewed Nicolet's notable accomplishments, including scientific achievements in a number of fields and major successes in promoting international scientific cooperation. The purview of the symposium was necessarily broad because of the scope of Nicolet's work. Topics included the structure and dynamics of the thermosphere, effects of solar variability and magnetospheric disturbances, ozone, and ionospheric coupling processes. The final session dealt with the complex chemical processes that take place and determine the ultimate fate of atmospheric contaminants in the mesosphere and stratosphere.

Nicolet's Accomplishments

Nicolet is an astronomer by training, receiving the doctorate in 1937 from the Univ. of Liege. His publication record extends over five decades and includes about 200 works in several fields: astrophysics, solar physics, meteorology, and atmospheric chemistry--and in each he has made fundamental contributions. Contrary to the current trend, most of Nicolet's publications are singly authored. In relation to the EGS symposium in his honor, Nicolet was among the first to publish on the structure of the ionosphere and the role of minor constituents in determining final states in multi-stepped chemical reactions in the upper atmosphere. Other accomplishments include the special role of nitrous oxide in the so-called D region, the special effects of diffusion, the persistence of atomic oxygen to high altitudes, and the extension of a helium belt to anomalously high altitudes thereby affecting satellite drag.

The quantitative aspect of Nicolet's work was unusual and influenced the development of the field because in his early years, unlike today, much of geophysical analysis was highly qualitative.

His multidisciplinary background and international scientific reputation enabled Nicolet to play a central role in one of the largest and most successful international scientific ventures ever completed. Nicolet was the secretary general of the governing committee that planned and supervised the International Geophysical Year (IGY) that extended from 1 July 1957 to 31 December 1958. The IGY, involving 64 nations and thousands of scientists, took place during the cold war. Both the US and the USSR were major contributors to the IGY, and even China participated. In many respects, the IGY and the launching of Sputnik in 1958 mark the onset of the space age. The IGY was the first scientific venture designed to study geophysical phenomena on a global scale. The scientific yield of the IGY was enormous, and its documentation includes thousands of journal articles and many books and monographs. Although none has been on the scale of the IGY, many subsequent international efforts have used the IGY as an organizational guide and inspiration.

Closer to home, Nicolet's presence in space science led to the establishment of the Belgian Institute of Space Aeronomy. The institute was founded in 1964, and Nicolet served as its first director.

The Symposium

Among the topics featured at the Nicolet symposium were recent results of the Dynamics Explorer (DE) mission. DE was launched on 3 August 1981 and consists of two polar orbiting satellites, one at low altitudes more suitable for thermospheric studies and the other at higher altitudes more suitable for studying the upper thermosphere and inner magnetosphere. A unique experiment included on the outer satellite is the imaging instrumentation consisting of three spin-scan photometers that operate simultaneously to produce 30-degree by 120-degree earth-centered frames (L.A. Frank, Univ. of Iowa). Images are made at three wavelengths--two visible and one ultraviolet (UV). When near apogee (3.65 earth radii), the satellite provides dramatic images of the full-scale auroral oval extending 360 degrees around the geomagnetic pole like a glimmering halo. Images are completed in less than 12 minutes, which is adequate to construct a cinematic presentation of temporal and spatial auroral variations for the first time.

Several authors discussed empirical and theoretical thermospheric models. New satellite results from DE, the Solar Mesospheric Explorer, and the Solar Maximum Mission have enlarged the empirical basis of the models. Empirical models use averaged conditions and at best give only a qualitative represention of a real-time situation. Theoretical models are quite elaborate but nevertheless are under continuous

development in attempts to include more physics and to use more computing power. Among the most serious inadequacies of current models are grid size, time dependent variations, and representation of electrical coupling to the magnetosphere.

Several papers dealt with atmospheric effects that result from the variability of solar radiation. UV and higher energy radiation is absorbed at high altitudes and represents a major energy input into the atmosphere above about 30 km. Stratospheric temperature changes are produced by variations in the solar cycle energy input and thereby affect chemical reaction cycles in the atmosphere. Direct and indirect effects on ozone were considered by several speakers. Reported DE observations of backscattered solar UV radiation provided direct synoptic observations of ozone absorption characteristics on scales of 3 to 120 km, depending on the altitude of the satellite.

The Nicolet symposium included 64 papers with one poster session, which was a first for an EGS meeting. The program of abstracts appears in the 21 December 1982 issue of EOS (Transactions, American Geophysical Union), and the proceedings will be published in Planetary and Space Sciences.

F.L. Carovillano

TECHNOLOGY

HELSINKI UNIV. OF TECHNOLOGY TARGETS RESEARCH TO MEET FINLAND'S NEEDS

The Helsinki Univ. of Technology is one of three technical universities in Finland and enrolls 56% of all Finnish technology students. It is located with and shares interlocking directorates with the Technical Research Center of Finland. A significant part of the university's operating funds comes from the Academy of Engineering Sciences in Finland and private foundations. The university has 370 full time teaching staff, including 80 full professors, and over 7,500 students. Although the university has active programs in many of the physical sciences, only those of low temperature physics and electrical engineering are addressed here.

Low Temperature Physics

Prof. O.V. Lounasmaa, director of the low temperature laboratory and Permanent Research Professor of the Academy of Finland, was on sabbatical leave at the time of my visit. The acting director, Prof. Matti Krusius, was on sabbatical from the Univ. of Turku.

There are currently four main research projects in the low temperature laboratory. The first is to investigate the use of nuclear magnetic resonance (NMR) for probing the brain. The work is conducted in a shielded room and uses a superconducting quantum interference device (SQUID). Spatial resolutions of 1 mm^3 within the brain have been obtained. A seven-channel SQUID magnetometer appears to be the key to the performance. Prof. T. Kohonen is trying to find out how the human brain organizes its associative and distributed memory. As a useful and profitable by-product of the NMR tomography, a technique that accurately determines the degree of curing undergone in newly poured concrete structures was developed. Pattern recognition techniques are used to identify changes in the NMR signatures of the concrete.

The second project involves millidegree Kelvin experiments with superfluid helium, but the effort is not directly related to electronics and will not be discussed further.

The third project is closely related to the second and involves critical flow effects in superfluid helium. The low temperature laboratory has found a condition in which only the helium nucleus is believed to cool.

The fourth project is to investigate nuclear magnetic ordering in copper. The low temperature laboratory's staff, believed to be the only group investigating this phenomenon, has found antimagnetic ordering in copper at temperatures below 100 nanodegrees Kelvin. SQUID and NMR techniques are used to obtain magnetic susceptibility and entropy.

Electrical Engineering Department

Closely associated with the low temperature laboratory is the work of Prof. T. Jokinen of the Department of Electrical Engineering (EE). He has already completed the development and testing of a 100-kW superconducting motor. Current work involves approaches toward more reliable liquid metal brushes and the design of a larger superconducting motor for installation in an icebreaker.

The liquid brush work is unique and impressive. Jokinen uses porous iron brushes, which provide a capillary action for a gallium-indium eutectic mixture rather than the more

conventional sodium-potassium metal. Current life tests, without oxygen, have been under way for 1,600 hours at 10 kA without appreciable degradation. The goal is to exceed the 2,000-hour operating season of the icebreaker. Other cryogenic work is in the EE Department's radio laboratory, where 1 to 2 GHz parametric amplifier work is being done.

The Electron Physics Laboratory is directed by acting head Prof. J. Sinkkonen, replacing Prof. T. Stubb, who has just retired. The group has virtually no silicon-oriented work and is currently investigating magnetic and optical semiconductors. Among these are the europium chaleogenides and CdMnTe.

The thin film group is working in Josephson junction technology to increase SQUID sensitivity and provide a more accurate voltage standard. Of great commercial interest is their research on indium tin oxide films for windows. The work is directed toward an efficient greenhouse effect, permitting transmission of visible light but reflecting infrared rays back into the building to conserve energy. (See ESN 36-10:253-254 [1982] for more information about a thin film deposition process in Finland.) New research is on thin planar humidity sensors, but details are not available.

In the optoelectronics group the latest work is in photonics. Single mode optical fibers are being grown by a chemical vapor deposition (CVD) process for new instrumentation applications. For example, a new ion-exchange process is being developed to fabricate single mode optical waveguides for the ring or optical gyroscope, one of the many instruments in which single mode fibers are used. In the process, spatially resolved electric fields are used to assist selectively the diffusion of silver ions to replace the sodium ions in the guiding films. The silver-bearing regions have a different index of refraction than the sodium bearing regions; thus, optical waveguides are formed.

Other photonics work concerns wavelength division multiplexing and multimode to single mode splitter-couplers. The photonics group is also working on solar cells using the deposition of amorphous silicon films, which are subsequently chlorinated. Within the group, 20% of the funding is from the Finnish post office; the rest is from other government agencies and industry.

The planar technology group, the largest in the EE Department, comprises 22 professionals. The group is silicon oriented and heavily emphasizes the design and testing of lithography masks. While the current emphasis is on optical lithography, an electron beam machine is expected in the next few years. In 1984 a new building will provide 330 m² of clean room facilities where complementary metal-oxide-semiconductor (CMOS) processing will be done. To prepare for the new capability, the current emphasis is on silicides and metallization technology. Quantum Hall devices are being investigated for possible use in establishing more precise standards for electron current.

Within the Technical Research Center, an active program in conducting polymers is growing. Headed by Dr. H. Stubb, the group is investigating piezoelectric and ferroelectric effects in various polymers. Current investigations are centered on a very heavy doping of the polymers (e.g., 20%) with $FeCl_3$. A model for conduction is sought. Infrared spectra of the various polymers are being investigated for correlation with stability. Combining the doping and polymerization steps appears to be one way to improve stability.

In astrophysics, a group is mapping the sun at 37 GHz, and an attempt is being made by the USSR to correlate such maps with neutron flux. There is some indication of a natural 160-minute cycle.

Finland has an abundance of peat bogs. Before the peat can be "harvested," however, it must be drained. The region must be probed for moisture content, depth, and nature of underlying soil. Until recently the probing was by mechanical coring--a labor intensive, slow process; it took several days to measure the water content. Recently the EE Department developed a radio-frequency (RF) probe to determine rapidly moisture content with no mechanical probing. A resonant technique is used; preliminary results indicate that the sharpness of the resonance is proportional to the heat of combustion of the peat. A related effort has resulted in an RF probe that can determine the "wetness" of snow. Until now this was done by time-consuming calorimetric means.

M.N. Yoder

NEWS & NOTES

A NOSE FOR THE NORTH

A recent article in The Times (London) described how scientists at

Manchester Univ. have tracked down man's ability to navigate by sensing the earth's magnetic field with magnetic materials in the head. Now a long-term study has located the magnets precisely: they are in the bones of the sinus. The human nose contains a compass, giving new meaning to the phrase, "Follow your nose."

The scientists, Robin Baker, Janice Mather, and John Kennough, examined seven skulls. They pulverized the bone from different parts of the skull, put the powder in a powerful magnetic field, and then checked to see if any magnetism was retained when the magnet was removed. Though the bones from various parts of the skull retained some magnetism, the only parts strongly magnetized were the bones of the sinus. Four out of five skulls showed this effect.

The one skull that contained no iron in its sinus bones came from an anemic. Blood contains iron, and it seems that the magnetic compasses are supplied with iron from the blood.

The discovery explains why humans can "feel" the earth's magnetic field. Other animals--pigeons, dolphins, even some bacteria--use this ability for homing and traveling. The discovery could explain the keen direction-finding ability of desert tribes and primitive people. Urban man probably still has this ability, but he is not accustomed to using it.

D. Mosher

FRANCE SET TO WIN WORLD'S FIBER OPTICS RACE

Louis Mexandeau, France's Minister for Posts, Telecommunications, and Telediffusion (PTT), has announced plans to cover over half the country with fiber optic cables by 1995. The world's first large scale trial of every-building fiber optic telecommunications is now under way in Biarritz, a town on the Atlantic coast where the Pyrenees mountains cast shadows that blot out TV reception.

By mid-1983 over 1,500 homes in the city will be wired with fiber optics. Thus, during the 1983 International GaAs Symposium in Biarritz, the world's leaders in gallium arsenide (GaAs) technology will be able to observe its application. (GaAs semiconductors are the primary technology used in fiber optic systems.) Eleven other French cities and over 100,000 homes are expected to be wired during 1983.

The PTT fiber optics implementation appears to be a key element of the slowly maturing Five Year Electronics Plan (see ESN 36-8:195 [1982]). French Telecom estimates that the near-term domestic fiber optics market is worth 45 billion French francs and hopes for several times this figure in exports.

M.N. Yoder

BRITAIN SEEKS FUTURE IN COMPUTERIZED INFORMATION TRANSFER

Responding to Japan's fifth generation computer project and the US Department of Defense's Very High Speed Integrated Circuit program, the UK's Department of Industry has released the Alvey Committee's much-awaited report.

The report recommends establishment of a comprehensive research program in four key technologies: very large scale integrated circuits (VLSI), software engineering, man-machine interfaces, and intelligent knowledge-based systems. The Alvey Committee believes that developing expertise in each of the four technologies is absolutely essential to the future competitiveness of the UK's information transfer industry.

The report proposes a program costing £350 million ($578 million) over a 5-year period and combining the efforts of industry, academia, government, and research organizations. The program would be in addition to the £3 million/yr Microelectronics Education Program and the Very High Performance Integrated Circuit (VHPIC) Program already under way.

Mr. Kenneth Baker, Member of Parliament and Minister for Information Technology (and an official known to "have the Prime Minister's eye") is expected to argue persuasively for legislation enacting the major objectives of the Alvey Committee's report.

M.N. Yoder

FRANCE STEPS UP ITS ANTARCTIC RESEARCH--AT THE EXPENSE OF THE RUSSIANS

Last year the French and Russians concluded a deal for the Russians to buy

fishing rights around the French island of Kerguelen in the South Indian Ocean. The French are going to use income from the transaction to increase their commercial and scientific activity in Antarctica.

In this year the French expect to spend in the continent ƀ12 million (about $20 million), an increase of 18%. They will use some of the money to hasten the completion of a 1,100-m airstrip at their Dumont d'Urville base. (According to the National Geographic atlas, the Dumont d'Urville base is the windiest place in the world, with screaming 200-mph gales sometimes coming down from the ice pack.) Scientific research will benefit from a 40% increase to some $5 million.

Besides the airstrip work, France is interested in the farming of such species as trout, salmon, shellfish, and krill, as well as oil and metal exploration.

France and the USSR are involved with a more purely scientific study of geomagnetism from a center on Kerguelen. Other joint projects will involve the US, Argentina, South Africa, Belgium, and Australia, and there are plans to take a Chinese party to the French Antarctic sector later in the year.

The British have long been involved in Antarctic research, and they too are increasing their efforts there. (From the New Scientist, January 1983.)

F.A. Richards

COMPUTER SIMULATION OF DISLOCATION IMAGES IN X-RAY DIFFRACTION TOPOGRAPHS

The number of materials science research studies involving x-ray diffraction topography is growing by leaps and bounds. Synchrotron topography facilities at national laboratories have allowed scientists in the Federal Republic of Germany, France, Japan, the UK, the US, and the USSR to obtain excellent results rapidly. Applying computer methods to interpreting images of dislocations has led to better definition of the conditions limiting resolution of the total defect characteristics.

Dr. Yves Epelboin, Laboratoire de Mineralogie-Cristallographie, associé au CNRS, Université Pierre et Marie Curie, 4 Place Jussieu, 75320, Paris, CEDEX 05, France, is becoming an established international expert on using computer simulation of images of dislocations and other defects within x-ray diffraction topographs to ascertain the precise nature of the observed defects. The method seems vital to the determination of defect structures in relatively complex crystals--for example, ammonium hydrogen oxalate hemihydrate (AHO) or $NH_4.H\,C_2O_4(H_2O)_{0.5}$.

Epelboin has described his initial work on numerical integration of the Takagi-Taupin equations governing the amplitude of the wave fields in an imperfect crystal so as to obtain a simulated image of a single dislocation line inclined to the surface of a silicon wafer (Acta Crystallographica A37 [1981], pp 132-133). While at IBM's T.J. Watson Research Center, NY, Epelboin investigated the "Determination of Burgers Vectors of Dislocations in Synthetic Quartz by Computer Simulation" (Journal of Applied Physics, 53 [1982], pp 271-275, co-authored with J.R. Patel of the Bell Laboratories). Account of elastic anisotropy was necessary for determining the dislocations having a Burgers vector equal to the smallest translation vector of the quartz lattice.

ESN has already noted Epelboin's involvement with the computer simulation of laboratory images of fringe structures at a stacking fault in a diamond crystal. The work was done by Prof. A.R. Lang, FRS, Univ. of Bristol, before he and his colleagues produced the first synchrotron topograph of stacking fault fringes (R.W. Armstrong, "Line XR7 for X-ray Topography and Interferometry at the Daresbury Synchrotron Source, UK," ESN 36-12:334 [1982]).

Figure 1 shows the latest result obtained by Epelboin and his colleagues at Paris with the varying step algorithm for numerical integration of the Takagi-Taupin equations applied to the inclined dislocation in silicon. The laboratory section topograph is a $(33\bar{3})$ reflection with Mo Kα radiation as obtained by Dr. M. Lefeld-Sosnowska, Univ. of Warsaw. Figure 1 shows the simulated images at four positions spaced about 5 μm along the entrance surface of the wafer, and gives a schematic view of the crystal diffraction geometry. As noted in the figure, the results were obtained with Program DEFV, which is available to the public. Requests should be directed to Epelboin at his university address.

R.W. Armstrong

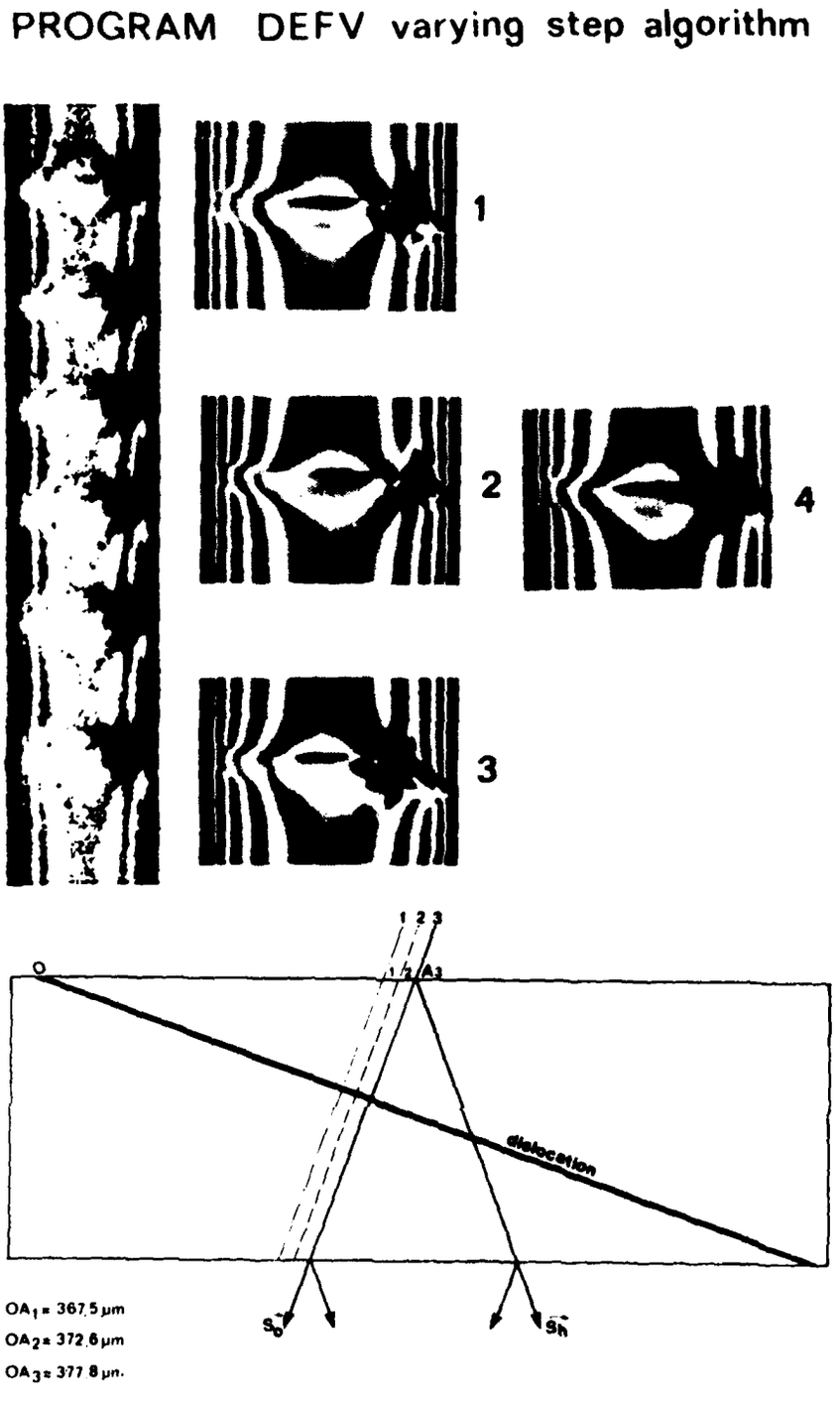

Figure 1. Topographic results obtained with program DEFV.

ENZYME AMPLIFIED DIAGNOSTIC PROCEDURES

Radioimmuno assay (RIA) uses "detector" molecules that bind specifically to "markers." The markers may be caused by a condition or a disease, and the detectors can be counted because they are attached to radioactive isotopes. RIA technology has been spectacularly successful, but it requires very careful handling and elaborate equipment, and if the marker molecules are present in very low concentrations, the usual RIA methods may not be sensitive enough to permit reliable identification.

Enzyme amplification is a rather different approach to assaying. Instead of counting the radioisotopes of a nonfunctional group attached to the detector as in RIA, a functional catalytic molecule or enzyme, say A, is introduced. The enzyme produces a molecule that can be counted. When the molecule reacts to an antibody, A can convert many molecules of X into Y. Now a second enzyme B is introduced in a form that, although inactive, can be activated. If there are 1,000 molecules of B for each molecule of A, under the correct conditions, the enzymatic reaction of B will produce several orders of magnitude more molecules of the product Z than those produced by the original marker molecule. Such amplification theoretically should permit much more sensitive assays.

In Britain, IQ (Bio) Limited, Cambridge, has already patented over 100 such reaction schemes, all of which use the idea of substituting a functional enzyme for an isotopic detector label. Reportedly, if a detector molecule is available, existing enzymatic reactions may provide a practical assay procedure for a great variety of molecules. Some of the procedures are already commercially available in kit form. A Pap-test enzyme amplification kit is now being evaluated in British clinical trials and may be released as early as next summer.

N.A. Bond, Jr.

RUSSIAN CLOUD SEEDING

Remarkably successful production of "additional" rainfall in the Ukraine has been reported by the Ukrainian Regional Scientific Research Institute (English abstract in Soviet News Abstract Publication, 14 December 1982). It is claimed that frozen carbonic acid, which is ground to a dust just before application from an aircraft, produced an extra 150 to 200 cu in. of rainfall per hectare (10,000 m²) from November to March. The total experimental area was 500,000 ha.

N.A. Bond, Jr.

AUTOMATIC TICKETING IN BRITAIN AND JAPAN

To make it easier to buy tickets and stop ticket frauds in trains and buses, a simple approach appears to be reasonable: install automatic ticket machines. A passenger would be required to have a ticket to enter the system through a barrier; at the destination another screening system, perhaps also automatic, would check the ticket again to be sure that the passenger had paid enough fare. Those without a ticket could not enter or leave the system without going through a special processing facility.

The realities of automatic ticketing may be far more complex than such a simple model. In many London underground stations, a ticket queue is still the rule, although ticket machines are everywhere. In London, an expensive set of automatic ticket machines will be withdrawn in May 1983. The machines proved to be unreliable in practice, with one or more in a bank of two or three likely to be out of order. The machines held a lot of information and supposedly could issue any fare on the system, including all the discounts, round trips, special day rates, and so on.

They could not, though, be easily modified to take the new 20 pence or £1 British coins, and there are so many people traveling on weekly or season passes that "exit monitoring" by London Transport employees is still required. And this leads to the possibility of fraud. For example, a passenger might buy a cheap ticket to enter the system; at his destination, he might give the human collector a small tip in order to get past, and thus defraud the system.

Japan has had better results, and reports a successful "total automation" of short-journey train operation. A new unmanned train in Kobe has already carried 21 million passengers on a special short line several kilometers long; the line links the middle of Kobe to the man-made resort of "Port Island" in the harbor. For a while, the train

carried a driver who just sat there except when something went wrong. But during the summer of 1981, when Port Island opened, the system ran completely automatically, with no staff members aboard. Elaborate precautions were taken to prevent accidents. Only a few difficulties have been reported; most of these have involved a person getting a hand or foot caught in the automatic doors. Really serious incidents--passengers kicking out doors or windows, for example--have been reported on an average of less than once a week. A great deal of trouble, incidentally, was taken to install many telephones in automatic trains; it was hoped that passengers would use them when some unusual incident occurred. However, the phones were never used; when something happens, people try to leave the car at once, and do not call the dispatch center.

Automation also can help authorities monitor the use of a system, even when people are still involved in operations. British Rail is now evaluating a portable ticket-issuing machine (PORTIS), which will be carried by train conductors on long-haul inter-city trains. To print a ticket, the traveling conductor keys in ticket information, which is then stored in a small memory cartridge. At the end of a run, all the stored ticketing information can be dumped from each PORTIS unit. The technology resembles that developed at Loughborough Technical Univ., UK, for utility-meter readers; in that application, the employee never really reads anything, but just holds the sensor next to the meter, and the device automatically accumulates the data. The PORTIS train conductor device will benefit from probability-of-use statistics; the most popular stations in the system will be the most easily coded entries on the keyboard. With all tickets being issued by computer-aided devices, British Rail management can have accurate and rapid hard-copy printouts of all statistics regarding the use of the system.

N.A. Bond, Jr.

AUTOMATED TESTING AT CAMBRIDGE

Computer-aided testing is now being done in several European countries. The West German military personnel offices in Bonn, for example, have some automated test systems on line now, and large-scale applications are expected in Scandinavia soon. A recent trial at the Applied Psychology Unit (APU), Cambridge, England, gave some positive preliminary results and should encourage further installations. Fraser Watts and Alan Baddeley were the investigators.

Several groups of normal subjects took the Raven Matrices and Mill Hill vocabulary tests in both the standard and computer-aided versions. Automated test-retest reliabilities were quite satisfactory, correlations of automated scores with standard ones were high, and total time for test administration was cut by 50%. When used on a group of elderly subjects and a sample of brain-damaged patients, the computerized procedures were also quite suitable. As an incidental sign of the validity of the automated tests, left-brain-damaged people tended to have lower vocabulary scores, while those injured in the right hemisphere showed lower scores on matrices; both findings accord well with expectations regarding performance deficit.

There was one precautionary note from the APU trial. Automated "norms" were slightly but consistently different from standard norms. Only large-scale testing can establish the extent of the possible bias or provide corrections for it. But the overall message seems to be clear: automated testing will gradually be adopted in Europe and will prove to be useful.

N.A. Bond, Jr.

CORRECTION

A clarification of the article entitled "Creating Better Solid State Energy Switching Devices at Imperial College" appearing in ESN 36-8:175 (1982) is in order. The 75% of the students not holding British passports relates only to the postgraduates.

ONR COSPONSORED CONFERENCES

ONR London can nominate two registration-free participants in the conferences it supports. Readers who are interested in such participation should contact the Chief Scientist, ONR London, as soon as possible.

7th International Conference on Infrared and Millimeter Waves, Univ. of St. Jerome, Marseille, France, 14-18 February 1983.

OHOLO Biological Conference on Mechanisms of Viral Pathogenesis (From Gene to Pathogen), Zichron Ya'acov, Israel, 20-23 March 1983.

First UK Solar Maximum Mission (SMM) Workshop, Oxford, UK, 9-12 April 1983

International Conference on Insulating Films on Semiconductors, INFOS 83, Eindhoven, The Netherlands, 11-13 April 1983.

Conference on Magnetic Resonance Spectroscopy of Liquid Crystals and Biological Membranes, Leeds, UK, 18-20 April 1983.

European Specialist Workshop on Active Microwave Semiconductor Devices, Maidenhead, UK, 4-6 May 1983.

8th European Symposium on Fluorine Chemistry (ESFC-8), Jerusalem, Israel, 21-26 August 1983.

EUROPEAN VISITORS TO THE US SUPPORTED BY ONR LONDON

Visitor	Affiliation	Organization to be Visited
Dr. J.D. Burton	Department of Oceanography The Univ. of Southampton, UK	NPG School, Monterey, CA NOSC, San Diego, CA (7-11 February 1983) Scripps Institution of Oceanography, Univ. of California, MIT (7-14 February 1983)
Dr. J.C. Duinker	Netherlands Institute of Sea Research, Den Berg, Texel, The Netherlands	Skidaway Institute of Oceanography Savannah, GA (5-8 February 1983) Gordon Research Conference on Chemical Oceanography Ventura, CA (30 January-4 February 1983)
Dr. S. Forsen	Physical Chemistry Div. Chemical Center Univ. of Lund Sweden	ONR Biosciences Lab San Diego, CA (13-15 February 1983) George Washington Univ. Medical School, Wash. DC (21 February 1983) ONR (21 February 1983)
Dr. R. Huber	Hochschule der Bundeswehr München Neubiberg, FRG	CNA, Alexandria, VA NPG School, Monterey, CA (June 1983)

Dr. K. Kremling	Institute für Meereskunde Kiel, FRG	Skidaway Institute of Oceanography Savannah, GA (7-8 February 1983) Gordon Research Confere on Chemical Oceanograph Ventura, CA (31 January-5 February 1983)
Dr. R.F.C. Mantoura	Institute for Marine Environmental Research Plymouth, UK	NOSC, San Diego, CA (6-7 February 1983) Univ. of Rhode Island (11 February 1983) Woods Hole Oceanographic Institution (9/10 February 1983)
Dr. H.J. Zimmerman	5100 Aachen-Kornelimünster Korneliusstr. 5 Aachen, FRG	NPG School, Monterey, CA Stanford Univ. (Both January 1983)

END

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